LECTURE NOTES
ON
FOREST ENGINEERING

VOLUME ONE

(BUILDING MATERIALS & CONSTRUCTION)

By:
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Indian Forest College,
DEHRA DUN.

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FOREST ENGINEERING

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FOREST ENGINEERING

PART I

BUILDING MATERIALS

SECTION 1. BUILDING STONES

1. Classification of Rocks.

1. Rocks may be classified in two ways, Geologically, based on the method of formation of the rock, and Scientifically depending upon the main constituents forming the rok.

2. Geological Classification:- Igneous Rocks are formed by consolidation of molten materials at or below the surface of the earth by gradual cooling, e.g., granite, basalt, trap etc. Aqueous or Sedimentary Rocks are formed by deposition of sand, gravel, clay, etc. generally by precipitation in water and cemented by silica, lime, potash, etc. under pressure, e.g. sandstones, limestones, laterite etc. Metamorphic Rocks are of igneous or sedimentary origin but subsequently changed or metamorphosed in colour, structure and texture, under the influence of intense heat and pressure exerted by the movements in or below the earth's crust, e.g. slates, schists, marble, etc.

3. Scientific Classification:- Silicious Rocks in which silica (sand, quartz or flint) predominates, e.g., granite, sandstone, trap etc. Calcareous Rocks in which calcium carbonate is the main constituent, e.g., lime stones, marble etc. Argillaceous Rocks which consists mainly of argile (clay) e.g., slates, laterite etc.

2 Requirements of a good Building Stone

1. A good building stone should primarily be
   - strong against crushing to bear the load.
   - durable to withstand the destructive influence of weather. A fresh fracture of a good stone should be bright, clean and sharp, free from loose grain sand earthy smell.
   - hard enough to withstand abrasive action, particularly when used for road pavements and in sharp corners.
   - heavy when required for underwater-construction but light when used in overhangs like vaults and domes etc.
   - compact grained indicating homogenity and greater strength. A fine-grained stone will be more durable than a coarse-grained one.
   - least porous to minimise absorption of acids which dissolve the constituents of the stone from inside. In cold climates, water absorbed inside may freeze and burst the stone due to increase in volume.
   - susceptible of easy quarrying and dressing in large sizes.

fire resistant particularly when used for chimneys, boilder lining, etc. to withstand high temperatures. Sand stones with silicates as binding materials are very good fire-resistants. Clay stones are still better, but are not quite strong and durable.

good in appearance (colour). Colours are however generally due to oxides of iron, which on exposure either fade away or disfigure and stain the surface due to rusting of the iron. Stones of lighter shades are therefore preferable.

3. Quarrying of Stones.

1. The best site for a quarry is on the side of a hill with exposed rock, above general ground level, so that it facilitates transport of quarried material down hill. Quarrying is therefore started from a side and top, and as it proceeds deep, an inclined track may be made for haulage of materials.

2. In stratified rock brushwood may be heaped on the surface and lighted which will cause the upper layer to expand and get separated. Alternatively, wedges may be drived along one of the beds which will split the rock. Even unstratified rock may be split along the desired line by using steel wedges every 10 cm (4") apart and driving them in simultaneously.

3. In very hard stones like granite, blasting is resorted A hole 2 to 3 cm (1" to 2") in diameter and 1 to 1.5 metre (3'-4') deep is jumped or drilled into the rock-face (Fig.1) A Bickford's fuse is inserted into the hole so as to project 20 to 30 cm (a foot) on the surface and the lower one-third the hole is then filled and tamped with a wooden rod. The remaining two-thirds of the hole is filled with moist clay or ant-hill earth, and well tamped and compacted. The fuse is then lighted with a match and all persons should retire to a safe distance of about 100 metres (yards).

4. Safety precautions:- Before firing, sentries must be posted all round to prevent men and animals entering the danger zone. During blasting, look up to avoid the flying debris. In case of a misfire, wait for half an hour before proceeding to investigate; do not try to remove the charge, but drill a hole by its side and fire a second charge which will blast the original charge also. In case of simultaneous charges in a number of neighbouring holes, arrange the lengths of the instantaneous fuses, so that explosions take place at not less than 10 second intervals and detail a person to count them.

5. Storing of Explosives: The explosives should be stored in an isolated shed, protected with a lightning conductor. The explosive must be packed in separate small cases, not heaped one above the other, but placed on separate shelves. Explosives and detonators should not be stored together.

No smoking or naked light should be allowed in the store, and where dynamite is stored the temperature of the room should not fall below 5°C (40° F). In very wet weather the boxes may be covered with water-proof cloth.

PLATE No.1 TO FACE PAGE 3.

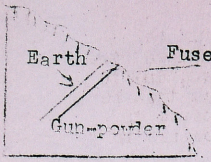

Earth
Fuse
Gun-powder

Fig: ROCK BLASING.

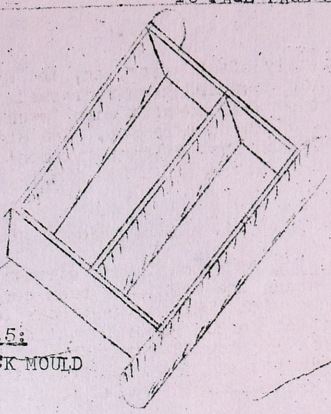


FIG.5:
BRICK MOULD

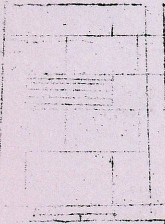


Fig.: 2 WALL.

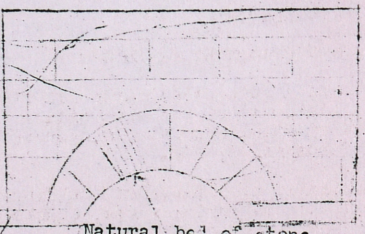

Natural bed of stone

Fig: 3 ARCH

FIG.4
RETAINING WALL.

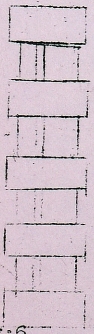


Fig:6
A STACK

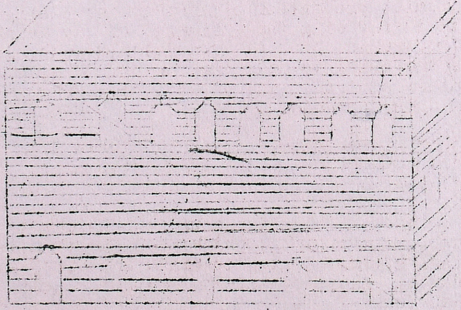


Fig:7 A BRKCK CLAMP

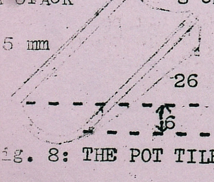


Fig. 8: THE POT TILE.

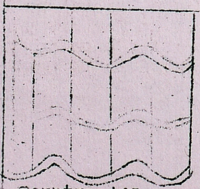


Fig. 9: Country tile roofing.

6. Immediately after quarrying, the stones should be roughly broken down and hammer-dressed to the required sizes, since the stone will be soft when freshly quarried, due to the presence of the quarry sap. The stones should then be allowed to season for at least six months by exposure to weather, before giving them the final dressing for use in construction.

4. Natural Bed of Stone

1. Natural Bed of stone is the direction of the layers parallel to which the stone has been consolidated. Stones must be placed with their natural beds perpendicular in the direction of the force. Thus in walls and columns, the stone must be placed with its natural bed horizontal; in arches, perpendicular to the central line of the arch, and in battered walls, perpendicular to the front batter (Fig.2, 3 & 4).

Section 2. Bricks

5. Composition of Common Brick Earths

1. The main constituents of a good brick earth are 20 to 30 percent alumina (clay) and 50 to 60 per cent silica (sand), and the remainder consists of lime, magnesia, manganese, oxides of iron, sodium and potassium, etc.

2. Clas imparts the plasticity necessary for moulding the bricks, but if it is in excess, the brick warps, cracks in drying, and becomes very hard during burning.

Sand produces resistance to heat, and durability, preserves the shape of bricks and prevents shrinkage, warping and undue hardness. If present in excess, however, it destroys cohesion, and renders the brick brittle and weak.

A small proportion of lime in the finely divided state assists in reducing the shrinkage of raw bricks, and also causes sand to fuse and bind the particles together. Excess of lime causes the brick to melt and run out of shape. A very small percentage of iron oxide gives a pleasing tint to the brick, and so does magnesia.

3. Harmful substances in brick clay:- Iron pyrites tends to oxidise the brick in the kiln, crystallise and split it into pieces.

Presence of alkalies cause the bricks to fuse, twist and warp. Further, the brick will absorb moisture, which on evaporation, leaves grey or white deposits, which mar the appearance. Clays containing salts are quite unsuitable for brick-making.

Pebbles of stone, gravel or lumps of earth should not be present; nodules of kunkar are particularly harmful, since they become quick-lime after burning and slake by absorption of water, causing the bricks to split and crumble to pieces.

4. Selection of brick earth:- A chemical analysis of the earth is not of much avail. The best course is to make a few bricks out of the available earth, burn them in an ordinary home fire, and put them to the usual tests. If the bricks crack in drying, it shows that the earth is too plastic and requires to be mixed with sand. If they break easily on throwing them on to the ground, the earth contains too much sand and can be improved by adding some clay.

6. Manufacture of Bricks

1. The operations involved in brick-making are preparation of the brick-earth, moulding, drying and burning the bricks.

2. Preparation of the earth includes unsoiling, clay-digging, weathering and tempering. 10 to 15 cm (a few inches depth of the top soil, including any pebbles etc., is dug out and removed to a distance.

A sufficient quantity of earth is then dug out, clods broken, and heaped in a bank about 50 cm (2') high, and allow to weather for some time. If sand or clay is to be mixed with the earth, it is done now and well turned over.

The clay is then cut, slashed and well-worked with spades and hoes, and tread well with feet, and so rendered soft by gradual addition of water. Just enough water should be used to make the clay soft and pasty and no more. Any pebbles or lumps of lime, grass, etc. are picked out; if these are present in large quantities, the clay can be washed with water and strained through a grating to remove the stones.

3. Moulding:- The brick mould (Fig.5) is generally made about 10% larger than the size of the bricks required, to allow for shrinkage of clay during drying and burning. It is a rectangular box with neither top nor bottom, made of any hard, seasoned wood, the edges being protected with strips of iron.

4. Two methods of moulding may be employed. In "slop moulding", the mould is dipped in water every time it is used to prevent the clay from sticking to it. In "Sand moulding", sand or ashes are sprinkled on to the mould before the clay is pressed into it. Sand moulding produces better shaped bricks, with sharper edges and roughrer surfaces than slop moulding, and should be prefered.

5. Moulding may be done either by hand or by machinery if they are required on a large scale, and again we may have ground moulding or table moulding. Only hand moulding on ground is described below, which may be usefully adopted in the interior of forests, where bricks are not locally available for purchase.

The surface of the ground is levelled watered and rammed to obtain a good working surface, and fine sand sprinkled on it. The moulder sits on the ground at the right-hand top corner, with a heap of tempered clay and a pot of water. The mould is dipped in water and placed on the ground, a lump of

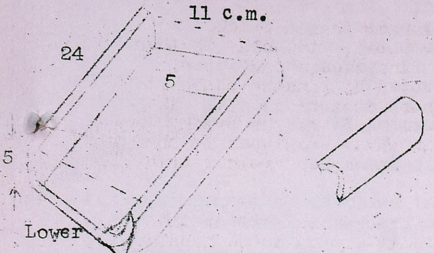

11 c.m.
24
5
5
Lower

Fig. 10: PAN TILE

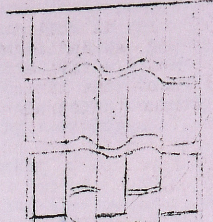
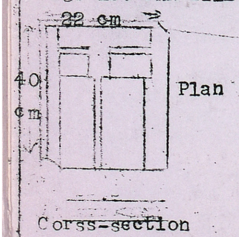


Fig:11: PAN TILING


22 cm
40 cm
Plan
Corss-section

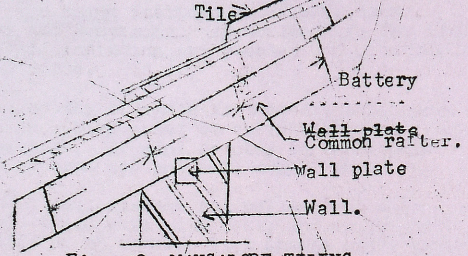
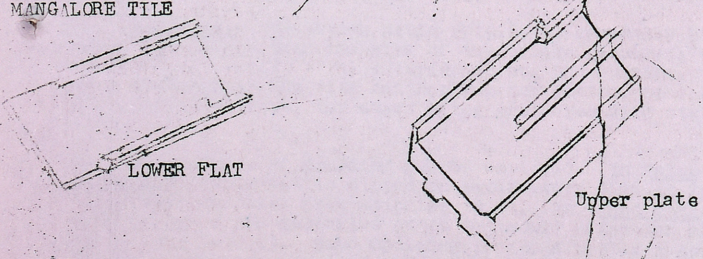
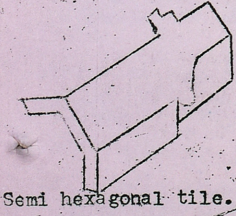

Tile
Battery
~~Wall-plate~~
Common rafter.
Wall plate
Wall.

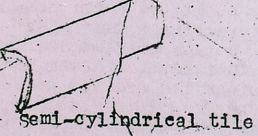
Fig: 13: MANGALORE TILING

Fig:12
MANGALORE TILE


LOWER FLAT
Upper plate



Semi hexagonal tile.



Semi-cylindrical tile

Fig:14
ALLAHABAD TILES

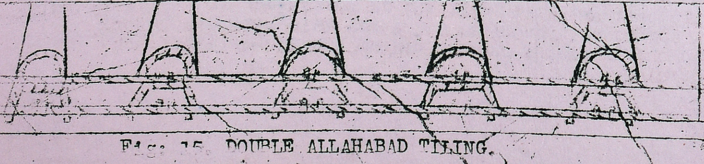


Fig: 15. DOUBLE ALLAHABAD TILING.

tempered clay is rolled up rather larger than a brick, lifted overhead and dashed into the mould; the clay is then pressed home to fill every corner. The excess clay projecting above the mould is then removed by passing along its top a strike (a straight edge of hard wood or steel). The moulder then gently lifts up the mould leaving the brick lying flat on the ground, dips it in water, replaces it on the ground close to the first brick, and makes another brick, and so on.

6. Drying:- The freshly moulded bricks are left on the ground for 24 hours; when they are dry enough to be handled, they are lifted up, cleaned and laid on edge until sufficiently dry. They are then stacked close to the clamp or kiln in tiers of 8 to 10 bricks on edge, the alternate layers being at right angles to one-another (Fig.6).

They should be left in the stacks for about 6 to 8 days until they are thoroughly dry. Damp bricks, when burnt, dry too suddenly and split or crack.

7. Brick-burning.- The object of burning the bricks is drive away the moisture out of the clay, and thus cause it to loose its plasticity, to fuse the contents into a homogeneous body, and to give the burnt product the requisite hardness to resist compression. Great care should therefore be taken to obtain a uniform burning throughout the stack.

8. Bricks may be burnt in clamps or kilns. Clamps are stacks of dried bricks skillfully built up over a system of flues, roughly formed with burnt bricks, whereas kiln is a permanent walled structure with built-in-flues, with control doors and chimneys. Only clamp-burning suitable for isolated works in the interior of forests is described below; though kiln-burning with control facilities to regulate the heat produces better bricks and a quicker out-turn, the initial out-lay makes it unsuitable for isolated small work.

9. The ground is first carefully levelled, consolidated and the bottom is set in a large rectangle with a small trench all round it to intercept any rain water. The lower flue walls are then built up with sun-dried bricks to a height of 50 to 60 cm (2') Fig.7, the upper courses being corbelled out to meet over the flues leaving a space between each pair of bricks, through which the fire will reach the fuel in the flues situated at right angles immediately above them. The flues are built up 10 courses-on-edge high, and with only one-brick walling between each other, the upper courses being corbelled out to meet at the top in the 10th course, and filled with firewood. Over this second fire of flues, 10 courses of bricks are set on edge, alternate courses being at right angles to one another, with a small gap between bricks, through which the products of combustion and the flame can pass. Then a third layer of flues with fuel can be laid just above and parallel to the first row of flues, and a second a layer of raw bricks set on edge, as before, and so on, until the required number of bricks are stacked for burning.

The top is then covered with two courses of flat bricks, and the whole stack is enclosed i a casing of raw-brick-in-mud, about 1½ bricks thick.

10. Fire wood in the lowest flues is then lighted and the draught regulated by opening or closing the flues partially. A slow fire is kept up until all the steam has disappeared from the top of the clamp (as indicated by the white smoke turning black). The top is then covered with a layer of earth, and the firing allowed to proceed rapidly until the sweating of the clamp reaches to within 30 cm (1') of the top of the casing. All the flues are then closed and the fuel allowed to burn out and cool.

11. In a carefully set clamp it is possible to obtain 60 to 65 per cent of first class bricks, 18 to 20 per cent of second class bricks, and 10 to 12 per cent of third class (over burnt or under burnt) bricks, and the rest would be brick-bats. If bricks are to be burnt, therefore, it would be necessary to allow for wastage in the kiln.

7. Fire Bricks

1. Fire-clay is the name given to clay which is capable of withstanding high temperatures without melting or becomin soft; the clay is then said to be refractory. It is composed of nearly pure hydrated silicate of alumina, usuall containing a large percentage of silica, and a little lime, magnesia, potash or soda.

A good fire clay should have a uniform texture, some what greasy to touch and free from any alkaline earths or iron oxides. A clay with course open grains will be found more refractory than fine-grained one. Fire clay also shrinks during burning by about 2 per cent.

2. The best sources of fireclay in India is the floor or mud-clay underlying coal-seams. This is generally found near Raniganj, Rajmahal hills, Karhabari coal fields, Barwai and Chanda coal fields, and also near Calicut and Mangalore.

3. Uses:- Fire clay is used for bedding fire bricks in the interior of boilders, flues, chimneys, fire places, cupolas and furnaces etc. where intense heat is developed. It may be used for making as-retorts, cruicibles, and every kind of potter's kiln-furniture such as slip-kiln bottoms, enamel kiln-linings etc. In the houses it can be used for setting stoves, ovens, backs of fire places and backs of cooking ra etc. It is also used for making fire-bricks, drain pipes, chimney pots, boiler arch bricks etc.

8. Characteristics of good brick

1. A first class brick should have---
   (1) Plane rectangular faces, parallel sides, and shar straight and right-angled edges.
   (2) Uniformity in size and colour
   (3) Fine, compact, uniform texture, and contain no fissures, air-bubbles, pebbles or lumps of lime-- examine a freshly cut surface.

(4) Sufficient hardness to withstand compression and cross-strain. It should give a metallic ringing sound when struck or when two bricks are knocked together; no mark should be made when scratched with finger-nails; should not break when dropped on ground from height of 2 metres (7').

(5) Least porosity and absorption. When soaked in water for 24 hours, it should not absorb water more than 15% of its dry weight.

2. For testing a consignment of bricks supplied by a contractor, select sample bricks from each of the quadrants of a heap and compare their qualities with the above specifications and judge.

9. Size of Bricks

1. Standard Size:- The standard size of clay bricks shall be
Nominal - 20 x 10 x 10 cm (9" x $4\frac{1}{2}$" x 3") or 20 x 10 x 5 cm.
Allowing for - 1 cm. (3/8") thick mortar joints, we may have
Actual Size - 19 x 19 x 9 cm. (8 $\frac{5}{8}$" x $4\frac{1}{8}$" x $2\frac{5}{8}$") or 19 x 9 x 4 cm.

2. Number of standard size bricks required for constructing 1 m^3 (100 cft.) of brick-work will be actually 500 (1422). But to allow for breakages and wastage during carting and handling, 510 (1450) standard size bricks should be allowed for building each cu.m (100 cft.) of brick-work. Thus for building a 2-brick wall 20 m (20) long x 3 m (10') high, number of bricks required are

$$\text{Volume} = \frac{40}{100} \times 20 \times 3 = 24\ m^3 \qquad \frac{3}{2} \times 20 \times 10 = 300 \text{ cft.}$$

$$\text{Bricks} = 24 \times 510 = 12{,}240. \qquad \frac{300}{100} \times 1450 = 4350.$$

SECTION 3 = TILES

10. Roofing Tiles.

1. Countitals tiles:- The pot tiles (Fig. 8 & 9) are generally semi-round, 270 mm ($10\frac{1}{2}$") long, and tapering from 110 mm ($4\frac{1}{2}$") dia. at broad end to 80 mm (3") at the small end, with a thickness of 6 to 10 ($\frac{1}{4}$ to $\frac{3}{8}$"). Number of these locking tiles required per 1 m^2 (100 cft) of roof would be 130 (1200).

2. The pan tiles (Fig. 10 & 11) are made on moulds and hence are more regular and uniform in size and shape. These are generally a little shorter in length, but wider and less curved than country tiles.

3. The Mangalore Tiles (Fig. 12 & 13) are a type of flat roofing tiles with lugs or a rib on the underside to rest against battens. Those manufactured in South India are generally 40 x 20 cm (16" x 9") size and 15 (130) tiles will

be required to cover 1 m^2 (100 sft) of roof. Those manufactured in Kanpur are bigger and only 12 (100) tiles are needed for 1 m^2 (100 sft) of roofing area.

4. The Allahabad Tiles (Fig.14 & 15) comprise of the flat, semi-hexagonal, semi-cylindrical, ventilating, ridge, hip and eaves tiles. For single tiling 1 m^2 (100 sft.) of roof, 12 (105) flats and 12 (105) half-rounds are needed. For double tiling, 12 (105) lower and 12 (105) upper flats, and 12 (105) half-rounds and 12 (105) semi-hexagonals are needed.

SECTION 4--LIMES

11. Classification of Lime

1. There are mainly two varieties of lime, viz., Fat lime and hydraulic lime.

	Fat lime	Hydraulic lime
Composition	Obtained from sea-shells, coral stones, and limestones containing calcium carbonate mixed with free sand or silica, soluble in acids.	Obtained from limestone or kunkar containing calcium carbonate intimately mixed with 10 to 30% of sand, clay and magnesium carbonate.
Slaking	Slakes rapidly with water giving out a large amount of heat, making hissing and cracking noise, and increases 2 to 2 times its original bulk.	Slakes very slowly, without producing much heat or noise, and there is very little increase in volume.
Shrinkage	Shrinks much and might crack as it dries. So a larger quantity of sand must be mixed in making mortar.	Has a much less tendency to shrink and crack. Less quantity of sand required for making good mortar.
Setting	Quick lime is $Ca(OH)_2$ and sets partly by evaporation of water but mainly by absorption of CO_2 from air. It should therefore be used only in plaster, pointing and white-washing of buildings, where air can reach. It cannot be used in mortar, flooring, foundations or under-water work where air is excluded.	Hydraulic lime hardens and sets by interaction of the constituents, forming silicates and aluminates of Calcium in the presence of water and does not need CO_2 for setting. It can therefore be used in any portion of a building. But it is dull and hence is not used in plaster, pointing or white-washing.
Strength	Crystals of $CaCO_3$ formed are not so strong.	The silicates and aluminates formed are as hard as stone.

2. Fat lime can be made hydraulic by mixing with it surkhi (finely powdered brick pieces) and grinding the mixture in a mortar grinding mill.

12. Burning of Limestone

1. Limestones may be burnt either in a clamp or a kiln. A clamp consists of a heap of alternate layers of limestones, broken to 5 to 8 cm (2 or 3") sizes, and fuel (generally hard coke or cinders), having a fire-hole below, and covered with clay or earth sods to prevent escape of heat. However this is a very wasteful method of burning and also the burnt lime will be mixed with a lot of ashes, etc. and hence it is rarely adopted.

2. A lime-kiln may be worked either on the intermittent or on the continuous system; the intermittent system, being the one that may be suitable for some isolated burning in the interior of the forests, is only described below.

3. The kiln may be of two types:-- (a) that in which the limestone and fuel are in contact with each other, and (b) that in which they are not in intimate mixture but the products of combustion burn the limestone. The latter type yields a better lime since there is no contamination with ashes, while the former method is more economical.

4. An intermittent kiln of the contact type is shown in Fig. 16. A circular space, about 2 m (6') in dia. is cleared to a depth of 25 cm (9") and packed with rubble stones or bricks on edge, and a mud wall built around it, 2 m (6') high, and 50 cm (2') thick at top, provided with four vent holes about 30 cm (1') dia at the base. On the floor is laid a layer of straw, dry leaves, wood shavings, brush wood, etc. the kiln is half-filled with wood fuel, and then limestone broken down to 8 cm (3") size is heaped up in the form of a conical mass. The fuel is kindled, and the top is either covered with ashes or plastered with mud to prevent escape of heat. When the fire has burnt itself out, the whole mass settles down, and the kiln is allowed to cool.

5. Fig. 17 shows an intermittent lime of the non-contact type or Flare Kiln as it is called. Here there is generally one or two draw-holes, around which 15 to 25 cm (6 to 9") size non-splitting limestones are packed in the form of an arch or dome, and over them the rest of the limestones broken down to 8 cm (3") size are lossely packed. Fire is lighted in the space below the arch, and the flame and products of cumbustion pass through the stones and burn them up. The heat should be applied gradually, so as not to split the arch stones.

13. Storing of Lime

1. All lime must be used within 24 days of removing from kiln. It must be stored in a covered, perfectly dry place in one large heap and air excluded in all possible ways; otherwise it will absorb moisture and carbon-dioxide from air and partially slake and harden. It should be slaked just before use and used up within 2 days of slaking, until used, it must be kept under water.

SECTION 5--SAND

14. Specification

1. Sand shall be inert and free from deleterious materials like acid, alkali, animal or vegetable organic matter. Coarse sand is preferable to fine sand, since fine sand reduces strength and leads to greater shrinkage. It should be sharp, clean and coarse; the grains must be compact, of durable minerals, and the size of grains so graded as to give a minimum of voids.

2. Bulking of sand:- Sand, when it absorbs moisture upto 5%, increases in volume by 20 to 25%, but when moisture increases beyond 10%, the sand gets back to original volume. This temporary increase in volume of moist sand is known as bulking of sand and has a great bearing on the quantity of sand to be used in mortars and concretes. When sand is wet, slightly more sand should be used than indicated by the proportion of mortar.

15. Sources of Sand

1. The Pit sand has sharp angular grains, due to accretio of particles, by their being cemented together by iron oxide But they contain a lot of clay and other impurities and hence it is eminently suited for road works only.

2. The River or Lake sand is perfectly clean, being washe continuously by water, but has rounded grains due/constant/ to abrasion. This is used for plasters, mortars and concrete works

3. The Sea-Sand contains a salt-coating which attracts moisture and makes the place damp and unhygenic. It is generally used only for under-water works.

16. Classification

1. Fine Sand to pass through 1 mm (1/16") mesh; generally used for plaster.

2. Coarse sand to pass through a 3 mm (⅛") mesh and is normally used for mortar and concrete.

3. When sand contains pebbles, or large particles, it is screened to get coarse sand, and sieved to get fine sand. If it contains leaves, straw, wood shavings, or other organic impurities, it should be well washed in a current of water before using it.

17. Substitutes for Sand.

1. Burnt brick bats, tiles, soft stone, or cinders are often ground to be used as fine aggregate when sand is not available locally. Rock dust of a stone quarry makes a very good substitute for sand.

SECTION 6. CEMENT

18. Properties of Portland Cement

1. Portland cement is the material produced by heating to a clinkering temperature an intimate mixture of calcareous, siliceous and aluminous constitutes, and finally grinding the resulting clinkers to a fine powder.

2. Good portland cement should be grey or greenish grey in colour.

3. The weight of a well-burnt cement should be 1.4 kg/dm^3 (90 lb/cft) or 50 kg (112 lb) per bag (36 dm^3 or $1\frac{1}{4}$ cft)

4. It should be so finely ground that 100 g (4 oz.) of cement continuously sifted over a sieve of 30 x 30 holes/cm^2 (76 x 76/sq.in.) for 5 minutes should not leave a residue of over 1%, and when sifted on one of 72 x 72 holes per cm^2 (180 x 180/sq.in.) for 15 minutes, the residue should not exceed 10%.

5. A sound cement, when mixed with water, should neither expand nor shrink on setting, as it would cause distortion, cracking and crumbling of the work; this can be tested by the pat or bottle test.

6. Ordinary Cement should not start setting (the initial set) within 30 min. but complete the final setting within 10 hours. Quick setting cement should have an initial set of not less than 5 min. and a final set of not more than 30 min.

7. A neat cement briquette should have a tensile strength of at least 44 kg/cm^2 (600 lbs/sq.in.) after 7 days, while 1:3 cement-sand mortar briquette should have a tensile strength of not less than 22 kg/cm^2 (325 lbs/sq.in.).

19. Storing of Cement.

1. Even for short periods cement should be kept in a dry, covered place to avoid caking by absorption of moisture. Cement bags should be stacked closely on a raised platform, away from the walls, and covered with a tarpaulin in wet weather.

20. Uses of Cement

1. Cement can be used neat by it-self, or as mortar, plaster or concrete. Cement is preferable to lime in the following situations:-

1. For construction in wet places or under water.
2. Where great strength is required as in multi-storeyed buildings.
3. Where a hard surface is needed as in projecting corners and copings etc.
4. Where quick-setting and rapid hardening are required.

5. For water-tight works.
6. For thin partition walls, like brick on edge wallings.
7. For pointing, filletting, etc.

2. But in the case of an isolated tall chimney or tower, subjected to heavy wind pressure, use of hydraulic lime mortar would be preferable, since lime is slightly elastic and able to take in the swaying force, while cement is rather rigid.

SECTION 7. MORTARS

21. General

1. Definition: Mortar is a mixture of lime or cement with sand, surkhi or cinder, and water, used in a plastic state for binding individual bricks, stones, tiles etc, etc. into one solid mess.

2. Objects of mixing sand in mortar are to prevent excessive shrinkage of lime or cement, to add strength to mortar, to increase the bulk thus reducing cost and to improve the setting power of fat lime (by making the mortar porous and helping absorption of CO_2 from air).

3. Properties required:-- (1) It should have easy workability, thus reducing labour in application and spreading.

(ii) It should stiffen quickly to ensure a reasonable speed in construction and should develop adequate strength in compression, tension and bond;

(iii) It should adhere well to the bricks to prevent penetration of moisture.

(iv) It should be durable, and should not affect the durability of other building materials.

4. Amount of mortar required may be estimated as follows:-

for 1 cu.m. (100 cft) of masonry 0.3 cu.m. (30 cft) of mortar.
1 cu.m. (100 cft) of brickwork. 0.25 cu.m. (25 cft) of mortar.

5. The lime or cement particles when mixed with sand will occupy the voids in sand and there is hardly any increase in the volume of the mixture. Hence the quantity of sand required will be the same as that of mortar required. The amount of lime or cement will then be according to the proportion desired.

Thus to obtain 1 cu.m.(100 cft) of cement mortar 1:5, we need 1 cu.m. (100 cft) of sand, and 1/5 x 1 = .2 cu.m. (1/5 x 100 = 20 cft.) or 5.6 (16) bags of cement.

22. Mud Mortar

Mud Mortar is made from stiff clay suitable for brick making, broken into a fine powder and thoroughly cleaned of grass, pebbles, etc. It is then mixed with water and well tempered before use. Some times chopped straw is well mixed with mud mortar to prevent heavy shrinkage.

2. Good mud mortar can be made even from black ~~cheap work~~ cotton soil with a suitable admixture of sand.

3. Mud mortar is used only in inferior and cheap work.

23. Lime Mortar

1. Lime Mortar is a mixture of lime and sand with water used in a plastic stage to provide an even bedding and adhesive material in masonary, brick-work and concrete, or for plastering and pointing. Hydraulic lime only should be used in mortar, and surkhi must be mixed with fat lime if hydraulic lime is not available, when it is sometime called surkhi mortar.

2. Proportion: The volume of slaked lime should be put slightly more than what is required to coat all the sand grains and fill the voids between them. The following proportions by volume are generally used:-

PURPOSE	PROPORTIONS				
	Hyd. Lime Mortar		Fat Lime Mortar		
	Hyd: Lime:	Sand	Fat Lime:	Surkhi:	Sand
1. For masonary brickwork and concrete	1	3	1	1	2
2. Plastering: Ist coat	-	-	1	0	2
2nd coat	-	2	2	0	1
3rd coat	-		4	0	1
3. Pointing	1	2	1	½	1
4. Terraces and bath room sink & floors.	1	2½	1	1	

3. Mixing: The slaked lime and sand are throughly mixed together or a clean platform, adding the required quantity of water. The mixture should be ground thoroughly in a mortar mill (Fig.18) drawn by bullocks or buffaloes or motor driven, for at least 4 hours, being continually stirred.

4. The blowing of lime can only be prevented by fine screeding of lime, thorough grinding of mortar and keeping it wet over-night before it is used.

5. Laying:- The bricks and stones should be well soaked in water before use to prevent rapid sucking of moisture from the mortar, thus rendering it a useless dry mixture unable to set. The mortar should be applied and quickly worked in with a trowel, smoothed over, and then not disturbed again.

6. Curing:- Lime mortar should be kept wet for at least 3 days after laying in position.

24. Cement Mortar

1. Cement Mortar is made by mixing cement and sand with water to the plastic consitency, taking 1 bag to cement as 35 cu.dm. (1.25 cft.).

2. Proportions:- Following proportions by volume are suitable:-

PURPOSE	PROPORTIONS	
	Cement :	Sand
(a) For Ordinary masonry or brickwork ..	1	6
(b) Water-tight masonry or brickwork ..	1	3
(c) Plastering building walls ..	1	5
(d) Plastering water-tight walls ..	1	3
(e) Pointing ..	1	4
(f) Terracing, bath room sinks and floors etc. ..	1	3
(g) For repairing surface defects in concrete. ..	1	2
(h) For grouting arches and old masonry.	1	1
(i) For water-proofing cement plastered surfaces. ..	1	0

3. Mixing:- Measured quantity of sand is heaped on a clear platform and the required quantity of cement spread on it uniformly. The two are then thoroughly mixed until the whole mass appears to be of a uniform colour. Small quantities of this dry mixture are then mixed with water added through a rose, sufficient for 10 to 15 minutes of work.

4. Laying:- Same as per lime mortar.

5. Curing:- Cement mortar should be kept wet for at least 7 days after laying in position.

SECTION 8. CONCRETE

25. General

1. Ingredients:- Concrete is an a-rtificial compound prepared by mixing lime or cement, sand (fine aggregate) and gravel or broken stone (coarse aggregate) and gravel or required proportions, so that the whole will set into a hard, dense and monolithic mass, free from voids, within a reasonable time.

2. The essentials of a good concrete are:-

(1) that the materials are clean, sharp, and the best of their kind.
(2) that they are thoroughly mixed in proper proportions.
(3) that the mix is carefully laid in position and consolidated, and

(4) that the work is thoroughly cured by keeping it wet until full strength is attained.

26. Lime Concrete

1. Proportions:- The following proportions are generally used to prepare mortar for preparing lime concrete:-

TYPE OF LIME		TYPE OF SAND	LIME	: SURKHI	: SAND
Hydraulic	..	Coarse	1	0	3
"	..	Fine	1	0	2
Fat	..	Coarse	1	1	2
"	..	Fine	1	1	1

2. Proportions of mortar to broken stone may be as follows:

Situation		Mortar	Broken Stone	Size of broken stone
Foundation in ordinary soils	..	1	3	5 cm (2")
" damp soils	..	1	2	5 cm (2")
Floors	..	1	2	4 cm ($1\frac{1}{2}$")

2. For roof terraces and bath-room floors, broken brick ballast 20 to 25 mm ($\frac{3}{4}$ to 1") guage is used in place of broken stones, and the proportions may be 1 lime mortar: $1\frac{1}{2}$ brick ballast as it makes a more water-proof surface.

3. Mixing: The lime mortar is first mixed and thoroughly ground in the mortar mill. The coarse aggregate is measured out on to the clean platform, soaked with water, and the mortar spread on it uniformly. The two are then turned over until thoroughly mixed, adding small quantities of water through the rose of a watering can.

27. Cement Concrete

1. Proportioning:- Cement is always measured out by weight, taking 1 bag to cement as 35 cu. dm. ($1\frac{1}{4}$ cft), while the aggregates--sand broken stone etc. are measured in bottom-less wooden boxes, generally, 30 x 30 x 39 cm = 35 cu. cm. (12" x 12" x 15" = 1.25 cft), which is equal to the volume of one bag of cement.

2. The following proportions are generally used for various works:-

SITUATION	Cement:	Sand:	Bromen stone	Size of broken Stone	
1. Building foundations					
(i) in ordinary soils ..	1	5	10	5 cm	(2")
(ii) in damp soils ..	1	4	8	5 cm	(2")
2. Ground Floors ..	1	4	8	5 cm	(2")
3. Bridge foundations, mass concrete in heavy walls and ordinary machine foundations. ..	1	3	6	4.5 cm	(1½"-2")
4. R.C.C. in floor and roof slabs, columns, arches, machine foundations subject to heavy vibrations and water-tight works below ground level.	1	2	4	2-2½ cm	(¾"-1")
5. Under-water constructions, R.C.C. in very thin sections and complicated moulds, and water-tight works above ground ..	1	1½	3	1-2 cm	(½"-¾")

3. The sand should be clean river sand, passing through a 5 mm (¼") screen and well graded. The maximum size of the coarse aggregate should not exceed 0.4 times the thickness of the work or 5 mm (¼") less than the clear space between the reinforcement rods, whichever is less. Water used in mortar or confrete must be clear, free from oil, acids, alkali and organic matter.

4. Mixing:- Sand is first measured out on to a clean platform, cement spread evenly over it, and the two mided thoroughly twice until the material attains a uniform colour of the cement. The coarse aggregate is then measured out on to the platform, the dry mixture of cement and sand is evenly spread over it and thoroughly turned over dry twice or thrice until a uniform mix is obtained. Portions of the dry mix are then drawn to a side and mixed with the required amount of water added through the rose of a watering can.

5. Water-Cement Ratio:- Water has three main functions in concrete, to wet the aggregates, to develop adhesion, to make the mixture plastic and workable, and to chemically combine with cement for setting and hardening processes. Hence there should be enough water for a full chemical action of cement; on the other hand the hydrated cement particles have to knit together so that less the amount of free water closer will be the knitting together. The ratio of this correct quantity of water by weight to that of cement is called the "Water Cement Ratio".

6. Consistency of concrete is a measure of its workability and depends upon the amount of water used in the mix.

Dry Consistency: Water 60 to 120 litres/cum.m (40 to 80 gall/100 cft) of concrete. It is just a damp mass and should be laid in 20 cm (8") layers and well rammed. It is used for mass concrete in foundations, floors concrete roads and pavements. It should never be used for reinforced work, and being porous, it is unsuitable for water-tight work.

Medium or Quaking Consistency: Water about 160 litres/cu.m. (100 gallons per 100 cft) of concrete. It is like a jelly, shakes on ramming, and is used for all ordinary works.

Wet Consistency: Water about 200 litres per cu.m. (130 gall./100 cft) of concrete. This is best suited for all reinforced concrete and water-tight works.

When in doubt start with a medium consistency and adjust the quantity of water to suit workability.

7. Quantities of Ingredients:-- Fuller's rule for the quantities of ingredients required for making 1 cu.m. (100 cft) of concrete is given by the formula

$$C = \frac{1.56}{c+s+g} \text{ cu.m.} \qquad C = \frac{156}{c+s+g} \text{ cft}$$

$$S = sC \text{ and } G = gC$$

where c:s:g is proportion and C, S, and G are the quantities of cement, sand and gravel or broken stone respectively in 1 cu.m. (100 cft.) of the concrete.

Thus the quantities of ingredients required for 1 cu.m. (for 100 cft) of 1:3:6 cement concrete are

cement $C = \frac{1.56}{1+3+6} = .156$ cu.m. or 4.5 bags $\qquad C = \frac{156}{1+3+6}$ 15.6 cft or $12\frac{1}{2}$ bags

Sand $S \quad \frac{3x.156}{1+3+} = 0.468$ cu.m. $\qquad S = 3x15.6 = 46.8$ cft.

and Gravel $G = 6x.156 = .936$ cu.m. $\qquad G = 6+15.6 = 93.6$ cft.

Amount of water W to be mixed with 1 cu.m. (100 cft) of concrete can be obtained from Prof. Abram's rule:

$$W = 100C \quad 4+3\ (S+G) \text{ litres/m}^3 \qquad W = C\ 2.5 + \frac{S+G}{50} \text{ gal/100 cft)}$$

Thus, quantity of water for mixing 1:3:6 cement concrete would be

$$W = 100x.156 \quad 4+3\ (.468+.936) \qquad W = 15.6 \quad 2.5 + \frac{46.8+93.6}{50}$$

$$= 127 \text{ litres per cu.m.} \qquad = 82.6 \text{ gal per 100 cft.}$$

28. Laying of Concrete

All concrete should be laid in position immediately after it is mixed with water in 10 to 15 cm (6") layers and thoroughly consolidated by ramming. Concrete should never be thrown from a height, but should be gently tipped into position; otherwise the ingredients would separate. Iron rammers weighing 5 kg (12 lb) should be used, and ramming continued till a skin of pure mortar (or cement wash) covers the surface and completely hides the aggregates. Wooden rammers may be used with brick ballast aggregate.

2. Joints in different layers of concrete, where necessary should be staggered and sloped off at an angle of about 30^0. Also the surfaces of the previously laid concrete should be roughened with pick-axes and well-watered before the next layer is laid.

29. Curing of Concrete

No water should be added during ramming, but the surface must be kept wet from the next day for at least 7 days for lime concrete and 10 days for cement concrete, so that the cement particles, knit together during setting, may combine with more and more water and increase in strength. This is known as 'Curing of concrete'.

30. Laying Cement Concrete Under Water

Concrete for under-water work should have a 1:2:4 mix and a quaking consistency. It should not be allowed to drop from a height through water as the ingredients would separate and the fine cement and sand may be washed away. One of the following methods may be used for depositing cement concrete for sub-aqueous works like bridge foundations, etc., where water cannot be excluded by coffer dams etc.:-

(a) By moulding large blocks on shore and lowering them into position.
(b) By filling dry consistency mixtures in jute or paper bags loosely and lowering them into position.
(c) Laying insitu through tubes reaching to the site or by lowering in buckets with hinged bottoms, which can be operated by chains from the top.

31. Water-Proofing Concrete

1. A dense concrete should be made by using properly graded aggregates and a rich mix. Further water-tightness may be obtained as follows:-

(a) By mixing some void filling materials with the concrete such as lime, wax, resin, allum, soap etc., or some patent water-proofing compounds like composeal, etc.

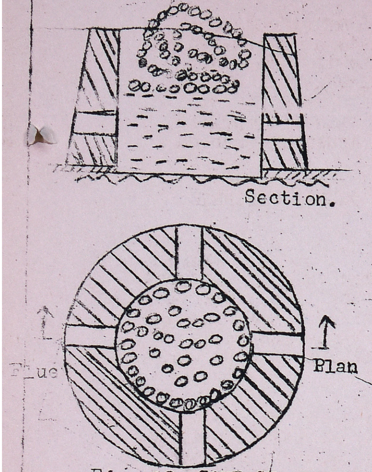
(b) By applying a water-proof coating of 2:1 cement mortar and neat cement paste using a metal trowel to give a glossy finish.

2. The following amounts of dry slaked lime may be used for water proofing cement concretes where necessary:-

Concrete mix	Dry slacked lime
1 : $1\frac{1}{2}$: 3	4% of wt. of cement
1 : 2 : 4	8% of "
1 : 3 : 6	16% of "

PLATE : 3

TO PACE ~~PAVE~~ PAGE 19.


Section.
Flue
Plan

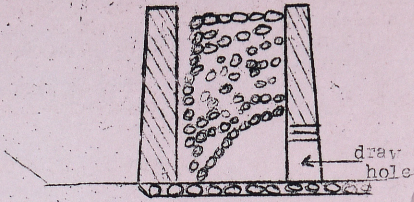


Fig: 17 NON CONTACT LIME KILN

Fig. 18. CONTACT LIME KILN.

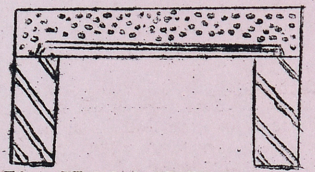


Fig: 19. BEAMS & LINTELS.

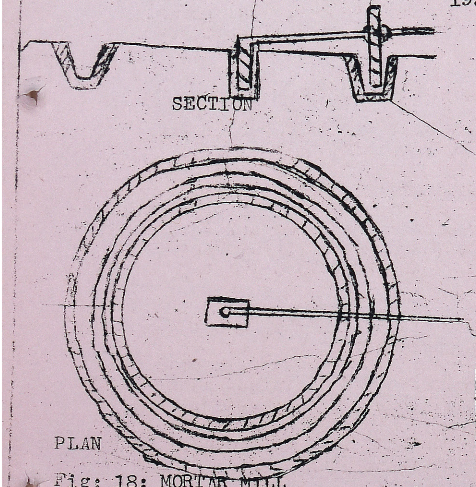

SECTION
PLAN

Fig: 18: MORTAR MILL

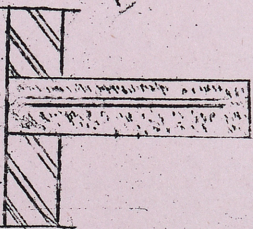


Fig:20: CANTILEVERS.

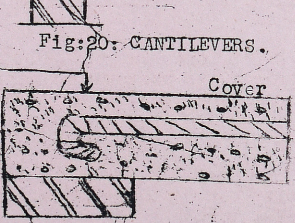


Fig.21: COVER OVER REINFORC

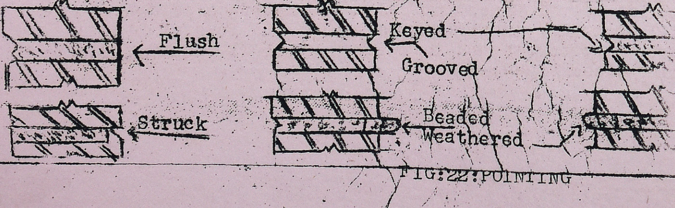

Flush
Struck
Keyed
Grooved
Beaded
Weathered

FIG:22:POINTING

3. Slaked lime is screened through 0.5 mm (1/40") mesh screen and mixed with water to form a paste at least 7 days earlier. The required amount of the paste is then added to the mixing water before concrete is mixed.

4. Paraffin wax, bitumen or asphaltic oils are applied hot on dry concrete surface with a paint brush and rubbed into the pores.

SECTION 9. REINFORCED CEMENT CONCRETE

32. General

1. Plain cement concrete has a very high crushing strength but it is very weak in tension. To overcome this limitation, steel, which has high tensile strength is introduced into cement concrete in the form of rods or bars in long and narrow members like lintels, beams and columns, and as wire-meshes for flat slabs or walls.

2. Advantages:- In R.C.C. both steel and concrete are used to best advantage most economically. Compared to steel, R.C.C. does not corrode, can resist heat, requires low maintenance cost since no painting or tightening up of bolts, revets etc., are needed, and only bars are needed which are easy to manufacture and transport; also materials are easily available, and it can resist earth-quake shocks. As against plain concrete, R.C.C. can resist both tensile and compressive stresses.

33. Location of Reinforcements

1. Imagine the R.C.C. structure to be made of rubber and the direction in which it would bend if similarly loaded, and place the reinforcements nearer the bulged or convex side which will be in tension. Thus in lintels, beams, slabs and foundation footings, etc. (Fig.19) which are supported at both ends, the bars will be placed near the lower surface, In pavement slabs, which are supported entirely, the bars are placed at the centre or about 5 cm (2") below the top surface.

2. Sharp bends in rods should be avoided; they should be bent exactly as shown on drawings, and arranged in proper position. The ends of all bars and stirrups must be hooked 180°. All bars must be wired together with No.16 guage binding wire, to keep them in position during concreting.

3. The positions of all reinforcements must be checked carefully before concreting commences, as they cannot be checked later.

4. Concrete cover over reinforcement is the distance from the outside of reinforcement rod to the surface of concrete (Fig.21), provided to prevent corrosion and loss of bond or grip between concrete and the bars. The following minimum cover are recommended:-

Slabs and panel walls, Retaining walls: 2 cm (¾")
Beams & columns, piles, water tight work:-
sides, top and bottom 3 to 4 cm (1"-1½") or bar diameter.
end cover 5 cm (2"); stirrups and binders 1 cm (½")
Foundation: 4 cm (1½")
Structures exposed to sea: 5 cm (2") for main bars.

For ensuring accurate cover, cement mortar blocks (1:2) of required thickness may be provided between the reinforcements and the forms.

34. Formwork or Shuttering

1. For placing and consolidation of concrete into desired shapes, forms or moulds are required. They are generally made of light but strong wood, and they should be rigid, durable and reasonably water-tight, easy to erect and take down. Generally tongued and grooved joints or bevel-edged planking with mud plastering are used. For rough works which are to be plaster-finished, just sawn timber is used, but when smooth finish is desired planed timber should be used.

The following thicknesses of timber would generally be found suitable:-

(i) Planks for slabs: 3-4 cm (1") planks supported at .6 to 1 m (2"-3") apa-rt by 5 x 10 cm (2" x 4") joists propped up at every metre (3')

(ii) Beams and girders:
Sides 2 to 4 cm (1"-1½") planks
bottom 4 to 5 cm (1½" 2") " supported 1 m(4') apart.
(iii) Column boxes: 3 to 4 cm (1"-1½") " --
(iv) Walls: 4 to 5 cm (1½"-2") supported at 1 m (3 ft.) apart.

2. The forms should be well greased on the inside to prevent concrete sticking to the forms; crude oil, soft soaps or even lime-wash may be used for this purpose.

3. Removal of forms-- In hot weather, forms for walls, columns, and sides of beams, can be removed after 2 to 3 days while supporting forms of slabs and bottoms of beams can be removed after 8-10 days. In cold weather, the form work should be left in place for at least twice the time. Forms must be stripped without shock or jarring, and after stripping the concrete surfaces must be kept wet for at least 10 days.

SECTION 10. PLASTERING

35. General

1. Objects of plastering are to give a true, plane, hard and smooth finished surface, to protect the bricks or stones from weathering action, to improve appearance and to prepa the surface for receiving white wash, distemper, paper or painting. External plastering is used only when second cla

and country bricks are used in construction. When table-moulded or wire cut superior bricks are used, the exterior needs only pointing to protect the joints in brick work. Stone-work is invariably pointed on the outside. The inside of buildings is generally plastered to provide improved appearance, more light and greater comfort.

2. The proportions of plaster would be as specified under mortar, only fine, white, river sand being used and well-ground Fat lime makes the best plaster, as any unslaked hydraulic lime may blister when in position.

3. 1 cu.m. of plaster would cover about 70 sq. metres of wall to 1 cm thickness (1 cft. to about 16 sq.feet of wall to $\frac{1}{2}$" thickness).

36. Lime plastering

The joints should all be raked out 1 cm ($\frac{1}{2}$") deep with a hook or trowel (and hammered), and the surface cleaned and well-wetted. The first coat of plaster 1 cm ($\frac{1}{2}$") thick is then applied roughly and rubbed with wooden straight edges to obtain a fairly plane surface; while still soft, this is freely scored over with the edge of a steel trowel to enable the second coat to stick firmly.

2. When the first coat has become firm vertical bands or screeds of plaster 3 to 5 mm ($\frac{1}{8}$" to $\frac{1}{4}$") thick and 20 cm/8") wide are laid at the corners and at 1 m (4') intervals along the face of the wall, and are adjusted to the finished level, to serve as guages to the rest of the work. The intermediate bays are then plastered flush with the screeds, being levelled by straight edges and wooden floats.

3. When this has set hard, the third coat of fine plaster 1 mm (1/16") thick is applied and well-floated with a steel trowel to get a smooth hard surface.

4. If only two coats of plaster are specified, screeds may be laid on brickwork direct and the middle coat described above may be omitted.

5. If only one coat is specified the screeds are laid on the brickwork direct and the work hand-floated as smooth as possible.

6. The finished plaster must be kept wet for at least 7 days and walls exposed to the sun be shaded with matting and kept damp.

7. Rendering:- When the surface of the wall is to be painted, the surface of plaster, when perfectly dry and set, can be rendered quite smooth by spreading on it lime putty (the hydrated lime settling down at the bottom of a white-wash tub) and rubbing down with a steel trowel until smooth.

37. Cement Plastering

1. Cement Plaster should always be laid in a single coat to the required thickness, 1-2 cm (½ to ¾") with the help of screeds at 1 m (3') intervals. The surface is best finished with a wooden float so as to remain rough. Where a smooth finish is desired, neat cement may be sprinkled on the surface and worked with a steel trowel until smooth.

2. Colouring of portland cement plaster may be effected by mixing it with a small quantity of iron oxide for red, yellow ochre for yellow or cream colour or other pigments as desired. Coloured cements are also available in the market now but are rather costly.

3. Cement plaster should be kept wet at least 10 days after application.

38. Mud Plastering

1. Composition:- Stiff clay with sometimes an equal volume of chopped straw or pine needles, and sand in the case of black cotton soils.

2. The clay is spread in the sun and powdered; the chopped straw or pine needles are added and thoroughly mixed dry. Water is then added and allowed to soak for two days; it is then mixed with the spades and tempered by treating, water being added as required, till it is of the consistency of stiff mortar.

3. Application:- It is spread evenly, 2-3 cm (1") thick on roofs and 1-2 cm (½" to ¾") on walls and floated with a straight edge until smooth and level. Any surface cracks which open up in drying are filled with liquid cowdung.

4. Leeping:- When dry, it is leeped with a mixture of cowdung, clay and sand (if needed). Roofs are leeped by hand, and walls with a float and trowel.

5. To make leeping, cowdung is steeped in water to free it of grass, straw, seeds, etc. 1 cu.m (c.ft) of clay for each cu.m (cft) of cowdung is added and the whole is thoroughly mixed.

6. Pargetting is a mixture of 3 parts of cowdung to 1 part of lime mortar, used for plastering inside of chimney flues, as it is heat-resistent.

39. General

1. Replastering:- When old plaster had deteriorated in portions, the portion of plaster is cut out up to the brick-work, the joints raked to depth of 1 cm (½"), wall-surface-well-wetted, and new plaster applied.

2. Plastering Cornice work:- The cornices are shaped in brick-work and then plastered with the help of a wooden template of required shape. The profile is first made at

intervals in plaster and the intervening spaces are then filled up with plaster roughly and shaped by moving the template to and fro.

3. **Plasters' Putty** is pure lime slaked with water to a creamy consistency, strained through a hair-sieve, and allowed to evaporate until it is stiff enough for use.

4. **Plaster of Paris** is calcined gypsum ground fine, and is generally used with lime putty (1:3) to make good defects and to give a superior finish to the wall, cornices, ceiling, etc.

5. **Rough-cast plaster** is a form of durable plastering made by mixing fine shingle with portland cement (1 cement : 3 shingle), throwing it on to the wall surface and finishing it by means of a wooden float or trowel.

6. **Pebble Dashing** is improved rough-cast plaster. The wall is first cement plastered, and then pebbles or small shingle are quickly and evenly passed into it and brushed with neat cement-wash to give a uniform tint.

SECTION 11. POINTING

40. Pointing

1. **Mortar**, as specified under mortars.

2. All joints are raked to a depth of 1 cm (½") and the surface cleaned of all dirt by scraping and rubbing with bricks or stones. The surface is then wetted thoroughly, a straight edge held just below a horizontal joint, mortar is placed in the joints and pressed with a trowel, until the joint is completely filled smooth and flush with the wall surface, taking care that the mortar does not spread over the surface.

3. **Curing**: Lime pointing should be kept wet for at least 3 days while cement pointing needs to be kept wet for at least 10 days after the work is finished.

4. The different kinds of pointing generally used are shown in Fig.21.

5. 3 cu. dm (1 cft) of mortar would be sufficient for flush or ruled pointing 1 sl. metre (100 sq.ft.) of brick-work surface, whereas 4.5 cu. dm (1.5 cft) will be needed for raised pointing. 1 sq.m. (100 sft) of stone work will need 2.25 cu. dm (0.75 cft.) of mortar for flush or ruled pointing and 4 cu. dm (1.25 cft) for raised pointing. Pointing 1 sq.m. (100 sft) of tile work will require 4.5 cu.dm (1.5 cft) of mortar.

SECTION 12

WHITEWASHING, COLOURWASHING AND DISTEMPERING

41. Whitewashing

1. Preparation: Fresh-burnt white or shell lime is slaked by adding it to water in a tub, constantly stirring it, and then allowed to stand for two days. It is then thinned by adding water to the consistency of cream, and strained through a clean, coarse cloth. To each tub-full of wash should be added 50 g (2 oz) of glue (gum arabic dissolved in hot water) or starch (kanjee) obtained from boiling 1 kg (2 lb) of rice to render the whitewash adhesive. A little blue (Cu SO_4) is also added to give brilliancy to the whitewash.

2. The surface to be whitewashed should be cleaned of all dirt and thoroughly dried. In re-whitewashing; all loose old whitewash should be scraped off, and all nail holes and rough edges caused by removal of old whitewash should be made good with the lime-putty. Greasy spots should be given a coat of kanjee and sand. If old whitewash is discoloured by smoke as in kitchens, and bathrooms, scrape off the old white-wash give it a coat of wood-ashes in water before applying whitewash. Any patches of new plaster during repairs should be given an extra coat of whitewash before the main white-washing starts.

3. Application:- The white-wash will be laid on with a brush, each coat consisting of one vertical followed by one horizontal stroke and each coat must be allowed to dry before the next is applied.

4. Three coats of whitewash will be necessary on new work and on scrapped surfaces, while the ordinary annual white-washing will consist of one coat laid on with vertical and horizontal strokes. In replacing old colourwash with whitewash, the old colourwash must be scraped off and two to three coats of whitewash applied as necessary.

5. The whitewash, when complete should form an opaque coat with smooth and regular surface, through which the plaster or old work cannot show.

42. Colourwashing

1. Colourwash is usually prepared by adding pigments to the strained whitewash, the following being the pigments in general use:-

For grey colour : Burnt coconut shells
Yellow or cream : Yellow ochre
Red : Red ochre
Buff colour : 100 g/(5 to 6 lb) of Umber and 50 g ($2\frac{1}{2}$ to 3 lb) of lamp black per cu.dm (cft) of lime or ramraj (brown earths).

Fawn Colour : 100 g (5 to 6 lbs) of umber,
25 g (1½ lb) of Indian red,
25 g (1½ lb) of lamp black
per cu.dm (cft.) of lime.

Green : 2 g (2 lbs) of fresh mango
bark boiled in water for
every gram (1 lb) of quick lime.

2. Preparation of wall and application of colourwash are same as specified for whitewashing. New or scraped surfaces should be given one coat of whitewash and one coat of colourwash. On surfaces which have been white or colourwashed before, one coat of colourwash should be sufficient.

3. In replacing one colour with another, old colour must be thoroughly scraped off, and a coat of whitewash given before the new colourwash is given; this is not necessary in the case of a new shade of the same colour being given.

4. Enough wash must be mixed at a time to cover a whole room or surface to be colour-washed or tints may vary, The wash should be stirred continuously during use.

43. Distempering

1. Distempers are really paints in which water or oil-in-water emulsion is the carrier. They consist of the pigment, glue and the carrier. Oil-bound distempers are also available in the market nowadays, and are washable.

2. Priming coat: Before applying distempers, a priming coat of ordinary size made by boiling glue in wa-ter may be given to the surface.

3. Preparation of surface and application of the distemper should conform to the items specified for whitewashing. Only durable distempers like the Duresco or the Hall's washable distempers should be used. Distempers should be applied only on thoroughly dry surface and in hot weather, using large flat, whitewashing brushes. On new walls 2 coats of distemper should be given over one coat of priming, and old walls need only one coat of distemper.

SECTION 13. PAINTING

44. General

Paint is an impervious coat laid on building materials to protect them from the effects of the atmosphere and for decorative purposes.

2. A paint consists of

(1) A base, a material which is opaque and possesses considerable covering capacity--generally lead, or zinc oxide.

(ii) An inert filler, used for diluting the base to make the paint lighter or heavier, and to reduce coat--generally gypsum, china clay barytes and whiting for white lead or zinc paints, and brick dust, and iron oxide for red lead paints.

(iii) A vehicle or carrier, a liquid of drying nature, capable of dissolving and holding in suspension both the base and the pigment; it enables spreading of the paint in a thin and even coat by a brush, enters the pores of the surface, hardens by the absorption of oxygen, and forms a durable and impervious skin-Generally linseed oil, raw or boiled.

(iv) A drier, to help the vehicle to thicken, and make it solidify rapidly--generally litharge, lead acetate etc.

(v) The pigment, i.e. colouring matter to be mixed with the base to get the desired colour.

(vi) A solvent, a freely-flowing liquid used for diluting the paint before application of the paint--generally turpentine. If used in excess, it flattens the colour and reduces the durability.

45. Preparation of Paint

1. The base is first ground in oil, then mixed to the required thickness with oil or turpendine. The pigment is separately ground on a flat stone or a colour-mill with a little oil and rendered fluid with more oil or turps. The two are then mixed together, and strained through canvas to remove any grit or lumps. It is then mixed with the drier before use.

2. Ready mixed paints are now available in any desired shade and should be used in preferance to mixing a point by an amature.

26. Chara-cteristics of a Good Paint

1. A good paint should be thin enough to be applied with a brush, but not too thin so as to flow down the surface. It should dry within a reasonable time, say 2 days. It should adhere firmly to the surface, and the painted surface should remain smooth, impervious and moderately wear-resisting. A good paint should have a large covering capacity; other things being equal, the covering capacity will depend upon the absorbency of the surface on which the paint is applied.

47. Application of Paint

1. It is best to supply the paints departmentally; where several coats are prescribed, each coat should be specified to have a slightly different tint to enable it to be passed before the next is laid on. The surface should be perfectly dry before being painted, and painting should always be done in hot weather. Each coat, of paint must be dry before the next is laid on. For outside work, only boiled linseed oil should be used, with as little turpentine as is essential.

2. Proper large brushes should be used for painting. New brushes should be soaked in water for 2 or 3 hours, shaken out and dried for an hour before use. After painting, the brush should be cleaned by dipping it in kerosene oil which should then be shaken out. Old brushes should be kept in water or raw linseed oil just covering the bristles for sometime before use.

48. Painting New Wood-work

1. Preparation of wood:- The work must be well seasoned and dry before painting; otherwise dry rot may set in. All nail and screw heads should be driven in 2 mm (1/16") under surface, and all knots and holes filled in with a first coat of red lead ground in water and glue size, laid on hot (to kill the know), the second coat of red lead ground in oil. In superior work, the know may be entirely cut out to depth of 2 mm (1/16") and filled up with Painter's putty made by grinding whiting to a fine powder and mixing it with raw linseed oil; sometimes workmen add fine wood dust to this putty and call it muck). All projections are then removed by plan~~t~~ing and sand papering, and the surface cleansed of all dirt.

2. Application of paint: A priming coat of lead ground with boiled linseed oil (7:4) is applied before painting, to form an opaque covering, filling up all the pores in the wood.

3. When the priming coat is dry, the whole surface is rubbed down with pumice stone or sand paper, all holes, cracks or uneveness filled in with painter's putty and the surface cleaned of all dust. Then the first coat of paint of the desired colour is applied evenly with a large brush, moving the brush perpendicular to the priming coat.

When this is dry, the surface is rubbed down with pumice stone or glass paper, and the second coat of paint applied moving the brush at right angles to the previous coat.

4. The final coat of paint should be applied along the grains of the wood and hence the previous coats should be adjusted to suit.

5. Flatting coat: If the painted surface is to be varnished, the final coat of paint is mixed with turps and little or no oil, so that its dries quickly without leaving the gloss of oil.

49. Repainting Old Woodwork

1. The old surface is washed down with pumice or soapstone, and washed with washing soda in water, until all dirt, grease, blisters and projections are removed. Any nail holes and cracks are filled up with muck, the surface brought forward with one or two touches of paint before commencing general painting.

2. If old paint has decayed or when a new coloured paint is to be used, the old paint should be completely removed and two or more coats of new paint applied. The best way of removing old paint is by burning it off with oxy-acetylens flame or by using a paint-remover; (a) Mix equal proportions of soap, potash and quick-lime in water, apply hot and keep it on for 24 hours, after which washing with hot water will remove all the paint; (b) Equal proportions of washing soda and quick lime are mixed in water to a creamy consistency, applied on the old painted surface and left there for an hour, after which the paint can be washed off with water.

50. Painting Iron, steel and Galvanized Iron

1. New iron and steel work should be thoroughly cleansed of all mill-scale rust, dirt and grease, by scraping with steel wire brushes and then given a coat of boiled linseed oil or a priming coat of paint. When the priming coat has dried, the second and third coat of the desired tint may be applied.

2. All iron and steel work should be protected from rust immediately on receipt by a coat of whitewash, until they are used in structures and painted up.

3. Galvanized iron requires to be well washed with hot water containing 500 g (1 lb) of washing soda to the bucketful before it takes paint properly.

4. Paints:- Lead paints, though liable to easy adultration, are the best for protecting iron and steel work; they can be tested by burning a sample which should yield $\frac{1}{2}$ kg ($\frac{1}{2}$ lb) of pure lead from 1 kg (1 lb) of paint.

5. For important iron or steel work, red lead paint should be used and may be mixed as follows:-

Red lead	9 kg (20 lb)	For 3 coat work, use $5\frac{1}{2}$, 6 and 9 kg (12,13 and 20 lb) of lead for the 1st,2nd, and 3rd coats respectively
White zinc	2 kg (4 lb)	
Raw linseed)= oil.)	4.5 litres (1 gal.)	
Turpentine	0.5 litres ($\frac{3}{4}$ pint)	

6. For unimportant works or for roofs, red oxide of iron paints may be used, mixed as follows:-

Red oxide powder dry	..	4.5 kg (10 lb).
Linseed oil raw	..	2.0 kg (4 lb.)
boiled	,.	0.5 kg (1 lb.)
Turpentine	..	5.0 kg (1 lb.)

A litre (gallon) of this paint will cover about 14 sq. metres (640 sq.ft.) for a first coat and 20 sq.m. (1000 s.ft.) for a 2nd coat.

7. For outside of steel water tanks, the following mixture will be good (chocolate colour:-

Red lead dry	2 kg (18 lb)
Raw linseed oil	0.5 litre (5 pints)
Lamp Black	100 g (1 lb)

This will make a litre (gallon) of paint and will cover 0 sq.m. (500 s.ft) a first coat and 10 sq.m. (600 sq.ft.) for second coat.

8. For inside of water tanks the following mixture (white paint) may be used:

White lead	10 kg (12 lb)
Boiled Linseed oil	2 litres (3½ pints)
Raw Linseed oil	3 litres (6 pints)
Turpentine	.5 litre (1 pint)

9. Repainting old iron and steel work:- All rust and blist should be carefully removed by scraping and brushing with stee wire brushes; the surface is brought forward by touching 3 or 4 touchings of paint, before starting repainting.

SECTION 14. VARNISHING

51. Varnishes

1. Varnishes are solutions of resins in oil, turpentine or alcohol. The preparation of varnishes is a difficult matter and it is best to buy them from reputed firms. The varnishes generally used are:

(i) Resin warnish, for cheap work, composed of resin ground in linseed oil and turpentine.

(ii) Copal varnish, which is pale and almost colourless, is used for interior decorations and furniture; it is made of copal, linseed oil and turpentine.

(iii) shellac varnish for high class ornamental work is made of pale shellack mastic and spirits of vine.

(iv) varnish for iron and outdoor work is made of tar oil, asphaltum and resin, heated together and cooled.

2. Application: woodwork should first be made smooth by rubbing with pumice stone or sand paper, killing the knots and stopping, if necessary. A glue size containing 100 g (1 lb) gum to a litre (gallon) of water is then applied as a priming coat and allowed to dry. The varnish is then smoothly laid on with a large brush and allowed to dry. A second coat may then be applied, if necessary.

SECTION 15. POLISHING WOOD-OILING ETC.

52. Polishing

1. Polishing are thin varnishes, which are solutions of shellack in spirit--about 150 g (1½ lb) of Shellac per litre (gallon) of alcohol, and require to be rubbed with a smooth cloth or cotton rag until the surface gets a brilliant shine.

2. Wax polish is made by boiling together 2 parts of melted bees-wax and 1 part of turpentine by weight; on cooling, it becames a paste, which is applied or to the wood surface and rubbed with a cloth or rag until a bright polish is obtained.

53. Wood Oiling

1. Woodwork not exposed to weather, as in roofs may be protected by a coat of oil instead of paints or varnishes which are costly. Good boiled oil spread in a thin film should become quite hard within 24 hours, while raw oil may take anything up to 15 days to dry.

2. Linseed Oiling:- 3 kg (3 lb) of double-boiled linseed oil and 1 kg (1 lb) of bees-wax are heated over a slow fire until the wax melts, and then 1 kg (1 lb) of turpentine added to it. This can then be applied to wood work in two coats.

3. Earth Oiling consists in applying crude oil or petroleum, warmed till it flows freely from the brush. In shingle roofs, a little red oxide may be mixed with the oil to colour the shingles red. One coat of oil applied every 3rd or 4th year on unpainted timber preserves the wood from insect attack and weather, and gives a nice varnished appearance.

54. Coal-tarring

1. Ingredients:- 4 parts of tar are thinned with 1 part of keresone oil, adding 200 g (2 lb) of slaked lime to every litre (gallon) of tar to prevent free-running.

2. Application:- The surface of wood or iron is thoroughly cleaned. The mixture is then heated to near boiling point and applied hot with a large brush or rag. Better results are obtained by dipping the article in hot tar instead of applying tar to it. Not less than 500 g (10 lb) of coal-tar should be used per 1 sq.m. (100 sq.ft.) of surface.

3. This is generally used for protecting fence-posts, door-posts and other timber embedded in the ground or walls.

55. Glazing

1. Glass: Unless otherwise specified, the glass used shall be sheed glass, free from flaws, specks and air-bubbles Always standard sizes of glass panes should be used, wherever possible to avoid wastage in cutting.

2. Rebates:- A rebate is cut into the door and window shutters and in the sash bars, when they are to be glazed. The distance between the rebates should be slightly more than the size of the panes; otherwise even a slight jar is likely to crack the glass.

3. Fixing:- The whole sash bar, but especially the rebate, is first primed with linseed oil to prevent the wood from drawing the oil from the putty. The back putty is then drawn along the inner edge of the rebates for bedding the glass, the glass pane is then placed in position, and secured by brads and front putty sloping from the inner to the outer

edge of the rebate. The putty is then covered with a coat of paint; otherwise the putty will shrink and get loose as the oil dries.

4. The Glazer's putty is made by mixing 100 g (2 lbs.) finely powdered whiting, 6 g (2 oz) white lead, 40 g (12 oz) of raw linseed oil, 3 g (1 oz) of litharge, and beating the mixture with a wooden mallet on a stone, until thoroughly mixed.

5. If the putty becomes hard on drying, it may be softened by warming it and working it again while hot.

6. In reputtying glass panes, all old putty should be removed carefully by applying dilute HC1 and leaving it for an hour. The rebates are thoroughly cleaned, and moistened with raw linseed oil before applying new putty.

7. Fixing glass by beading:- The glass is placed in the rebates, thin strips of wood about 10 x 10 mm (3/8" x 3/8") are placed against the rebate and nails driven through the beading into the sides of the rebates.

8. The glass is fixed on the outside when putty is used for fixing and on the inside when beads are used.

PART II

BUILDING CONSTRUCTION

56. Selection of Site

1. The chief considerations that govern the choice of site for a forest building are:-

(i) Situation and accessibility:- Select a place by a village near the centre of jurisdiction.

(ii) Good water supply:- For construction and domestic use. Select the site up-stream of a river from the village, or provide for a well.

(iii) Nature of soil for foundation:- For small structures ordinary earth, gritty gravel or morrum would be good; avoid black clayey soils, if possible. Foundation in rock would be unnecessarily expense for small buildings, since loads would be small.

(iv) Elevation and Drainage:- A slightly raised site and presence of natural drainage would be helpful, to keep the place dry and healthy.

(v) Aspect:- In hot climates, the building should face north or slightly north-east to avoid hot afternoons of summer. In cold climates, face it south or slightly south-west, to get as much of sun as possible in the winters.

57. Preparation of Site

1. Clear the undergrowth, and also uproot the trees standing on the site of building. Any termite mound should be completely dug out until the queen and is located and destroyed. If site is well chosen a few drains, around the building and site should be sufficient. If the soil is soft and impermeable, it may be necessary to provide sub-soil drainage i.e., trenches are dug criss-cross, deep below the foundation level and filled with boulders, broken stones, sand or gravel through which water can be led outside to natural drainage.

SECTION 17 - FOUNDATIONS

58. Object

1. The object of providing proper foundations is to distribute the loads uniformly over a sufficient area of the soil, so that there may be little or no settlement, and never an unequal settlement.

59. Causes of Failure and precautions

1. Forces inducing settlement such as unequal loading and unequal resistance of soil. The loads must be distributed so that load per square metre of soil is within its safe bearing capacity under all parts of the building.

2. Lateral escape of soft soils, like running sands and heavy clays should be prevented by sheet piling, etc.

3. Sliding of substratum on sloping ground - a retaining wall may be necessary.

4. Withdrawal of water from foundation soils like clay and black soils. Take foundations below the level of any adjacent cuttings so that water may not be drained away.

5. Weathering - Foundations must be taken at least 60 to 100 cm (2 to 3 ft) below ground level.

6. Wind pressures: Extend the foundation footing of the leeward side.

7. Lateral pressures such as thrusts by beams, vaults, arches, etc. support these thrusts by buttresses.

60. Choice of Foundation Soil and Preparation

1. Solid rock makes the strongest fondation, but is very expensive and unnecessary for small buildings. The surface is dressed to remove weathered layer, and levelled to provide a horizontal bed for the foundation to rest on.

2. An inclined rock surface may be benched i.e., cut in steps to reduce cost - Fig.23.

3. Ordinary soil, moorum, gritty gravel, and hard clay mixed with sand make very good foundations for all ordinary buildings. Trenches are excavated 60 to 100 cm. (2 to 4 feet)

deep, their bottoms levelled, a layer of concrete laid to distribute the load uniformly over the soil, and footings commenced, Fig.24.

4. Pure gravel and sand are almost incompressible, but should be prevented from escaping laterally, by sheet-piling all round the building, etc.

5. Made up and Black Cotton soil should be avoided where possible. If the black soil is only 50 to 60 cm (1 or 2 ft) deep, the entire soil over the site may be taken up, foundations taken into the good soil below, and the plinth filled up with good soil. If the black soil extends up to 1 or 2 m (4'-6') in depth, the foundations only can be taken to 20 cm (1 foot) deep into the good soil below. In deep black soil for small buildings, excavate a trench 50 cm (2') wider and deeper than the foundations required in ordinary clay, and provide a sand-filling all round it in the form of a bulb Fig.25, this ensures a proper dissipation of the load, and prevents differential subsidence of the soil to some extent. In the case of large buildings, special pile, well or raft foundations or sheet piling may have to be provided, and the building tied by R.C.C. bands at plinth, lintel and roof levels.

6. No building should be situated partly on hard ground and partly on soft or made up soil to avoid differential subsisdence.

61. Safe Bearing Capacity of soil

1. The Safe Bearing Power of a soil is the maximum load per sq.metre (square foot) of surface the soil can bear, without yielding in any direction after making due allowance for unknown factors. like nature of soil, and effects of different kinds of load. Thus Factor of Safety is the number representing what fraction of the ultimate resistance of the soil is taken as its S.B.C. Generally a Factor of Safety of 4 to 10 is adopted.

2. The following table gives the S.B.C. of some soils:-

Description of earth	S.B.C. in tonnes/ sq.m.	tons per sq.foot	Remarks
1. Soft yellow soils and ordinary ground ..	5	0.5	-
2. Black Cotton soil ..	5	0.5	Disperse load
3. Compact clay, nearly dry	20 to 25	2 to 2.5	by Sand bulb
4. Loose sand on shifting river beds ..	20 to 25	1.5 to 2.5	
5. Compact sand ..	20 to 30	2 to 3	
6. Compact sand prevented from spreading ..	50 to 70	5 to 7	
7. Red earth or moorum ..	30 to 40	3 to 4	
8. Compact gritty gravel..	70 to 90	7 to 9	
9. Rock ..	20 to 250	2 to 25	laterite granite

62. Loads on Masonry and foundations

1. The Dead Load:- actual weights of the building materials used in various parts of the structure.

2. The Live Load:- movable loads on roofs and floors, such as men and furniture, etc. and weight of snow on the roofs. Equivalent dead loads are prescribed by regulations for design purposes.

3. Wind Load:- on walls and sloping roofs.

4. All walls, columns and foundations, etc., should be designed to withstand the stresses imposed. The following tables give the necessary safe bearing stresses in masonry and Concrete, the dead and live loads to be considered for purposes of design:-

5. Safe Compressive Stresses:-

Description of item		Safe Compressive stress in tonnes/sq.m.	tons/sq.ft.
1. Ashlar masonry	...	150	15
2. Rubble work in lime mortar	...	80	8
3. 1st and 2nd Class Brickwork in lime or Cement mortar.	...	60	6
4. 3rd Class Brickwork in lime mortar		40	4
5. Cement concrete 1 : 2 : 4	...	200	20
1 : 3 : 6	...	150	15
1 : 4 : 8	...	100	10
1 : 5 :10	...	80	8
6. Lime concrete	...	70	7

6. Weights of Building Materials:-

Material		Weight in kg/cu.m.	lb/percft.
1. Earth and loose soil	...	1600	100
2. Gravel and rammed earth	...	1800	112
3. Brickwork	...	1920	120
4. Masonry	...	2400	150
5. Lime concrete	...	2000	120
6. Plain Cement Concrete	...	2240	140
7. Reinforced Cement Concrete	...	2500	144
8. Mortar and Plaster	...	2000	112
9. Timber	...	800 to 950	50-60
10. Iron and steel	...	7850	490
11. Water	...	1000	62.5

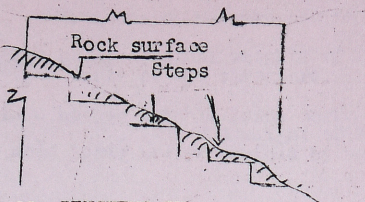

Rock surface
Steps

Fig.23: BENCHING IN ROCK.

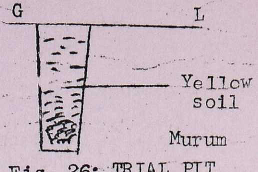

G
L
Yellow soil
Murum

Fig. 26: TRIAL PIT.

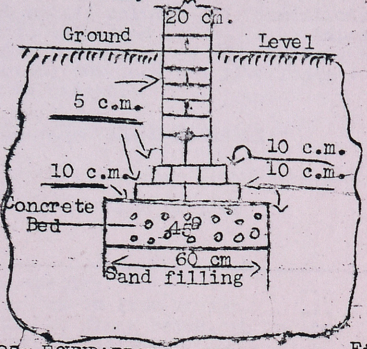

20 cm.
Ground
Level
5 c.m.
10 c.m.
10 c.m.
10 c.m.
Concrete Bed
45°
60 cm
Sand filling

Fig. 25: FOUNDATION IN DEEP BLACK SOILS.

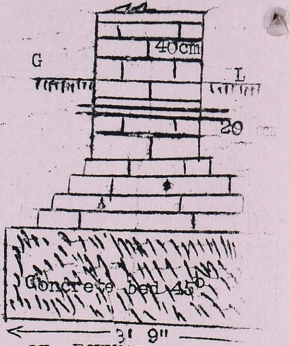

40cm
G
L
20
Concrete bed 45°
3' 9"

Fig. 27: FOUNDATION OF W

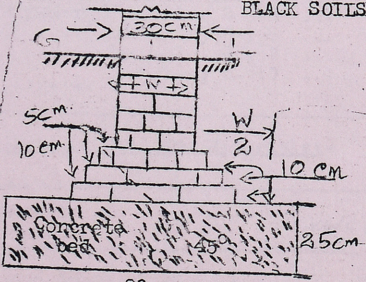

30cm
G
L
W
5cm
10cm
W/2
10 CM
Concrete bed
45°
25cm
80 cm.

Fig. 24: FOUNDATIONS IN HARD SOIL

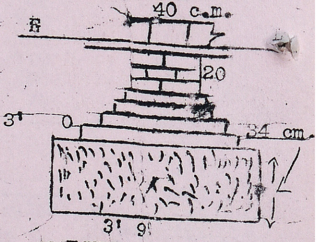

40 c.m.
G
L
20
3' 0
34 cm.
45°
3' 9"

Fig. 28 EPIMDATCPM PF 40 cm PILIAR

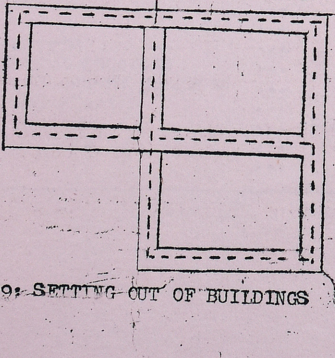


Fig. 29: SETTING OUT OF BUILDINGS

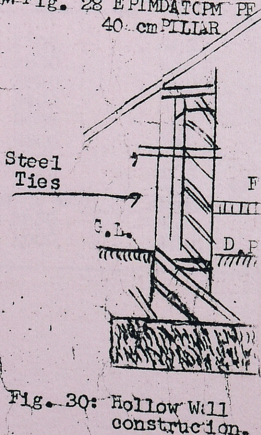

Steel Ties
F
G.L.
D.P

Fig. 30: Hollow Wall construction.

7. Weights of roofing materials:

Material	Weight in Kg/sq.m.	Weight in lb/per s
1. Corrugated G.I. Sheets 24 guage	7	2½
22 "	10	2
2. G.I. 24 Guage on 3 cm (1") boarding	30	5
4. 20 cm(2")thatch on ~~Bambo~~Bamboo frames	50	10
3. Mangalore tiles on batterns	50	10
5. Single Allahabad titles over battens	85	17
6- Double Allahabad tiles over "	165	34
7- Country tiles including bamboo frames, single	70	14
Double	120	24
8. Eterni sheets or tiles	12	2½
9. Asbestos cement sheets	35	7
10. Timber trusses and purlins	12	2½
11. Rafters	5.	1
12. R.C.C. and other flat roofs	25 per cm thickness	12 per in thickness.

8. Live loads:

Type of building	Equivalent dead load Kg/sq. m.	Equivalent dead load lb per sft.
1. Residential ..	250	50
2. Public buildings such as theatres, hospitals etc. ..	400	80
3. Offices, schools, dancing halls etc.	500	100
4. Assembly halls, Library etc.	550	112 ~~110~~
5. Factories, ware-houses, etc.	1000	200
6. Flat roofs used as terrace	250	50
7. " not used as terrace	150	30

9. Wind loads: The maximum wind may be taken as 3.8 kg/sq.m. (0.75 lb. sq. ft.) per degree of slope of the roof to the horizontal. Thus for a normal slope of 1 in 2 (pitch $\frac{1}{4}$ = 26° 34' slope), wind loand may be taken as 3.8 x 26.5 =100 Kg per sq.m.(or $\frac{3}{4}$x26.5=20 lb.per sq.ft.)

63. Examination of Ground for Foundations.

1. Inspection of site regarding nature of soil.

2. Probing is soft soils by driving a crow bar vertically until it reaches hard ground.

3. Open trial pits are the most satisfactory evidence of nature of soil--generally 1 to 2 metres (5to 6 feet) square at top--Fing. 26.

4. Boring- Post-hole earth-auger may be used in ordinary

soils for small building. When deep borings are needed for heavy structures, the core-drilling machines of percussion drilling machines may be used.

64. Footings

1. The bases of walls are to be increased to the width of foundation gradually by footings, the projections of each step beyond the one above it being called an offset, Fig.24.

2. In brick-work the offset is usually 5 cm (2¼ inch) so that any stretcher in the lower course may not be left) uncovered. The offsets in masonry footings may be 10 to 15 cm (4 to 6 inches), since larger stones may be used.

3. The number of offsets depends upon the increase in width required. All brick-work below ground level should be built in cement mortar to increase strength and stability.

65. Width of Foundation

1. Area of foundation, $A = \frac{W}{S.B.C.}$ sq. metres (sq.ft.)

Where W = total weight on soil, including weight of column or wall per metre (ft) length and 10% being added for weight of foundations.
S.B.C. = safe bearing capacity of soil.
A = Width of foundation x 1 metre (1 foot) for wall.
= Width x length, for foundation of a pillar.

Note:- The width of the bottom course of footing, coming immediately upon the foundation concrete, shall be twice the thickness of the wall, thus in a 1½ brick wall, this course would be 3 bricks wide. Offsets of 5 cm (2¼") are then left on each side of each course, until the desired wall thickness is obtained. It is preferable to double the thickness of the bottom course. see example below 67.

66. Thickness of Concrete Bed

The thickness of concrete bed may be found by drawing lines at 45^0 to the horizontal from top of footings to cut the vertical through the opposite edge of the concrete bed as shown in Fig.27, subject to a minimum of 20 cm (8"), or by the formula, thickness of concrete bed = 5/6 x thickness of wall.

67. Depth of Foundation Below Ground level

Rankine's formula gives:-

$$d = \frac{P}{W} \left(\frac{1 - \sin \phi}{1 + \sin \phi} \right)^2$$

where d = depth of foundation bottom in metres (feet).
p = Pressure of soil in kg/sq.m. (lb/sft).
w = weight of soil in kg/cu.m (lb per cft).
and ϕ = angle of repose of the soil in degrees.

Note:- A minimum depth of 60 cm to 1 m (2 to 3 feet) below ground level should be provided in any soil to keep the foundation beyond the effects of weathering.

The following table gives weights and angles of repose of some soils:-

Description of soil	Weight Kg/ cu.m.	 lb/ cft.	Angle of repose Ø	Sin Ø
1. Very wet earth or wet clay	1450	(90)	15°	0.2088
2. Wet sand or gravel with sand	1600	(100)	25°	0.4226
3. Dry earth, clay and sand	1600	(100)	30°	0.5000
4. Moist earth or shingle sand	1600	(100)	40°	0.6428
5. Clean gravel	1800	(112)	45°	0.7071

Example 1: Design the width and depth of the foundation bed for a two brick wall carrying a load of 15 tonnes/metre (6 tons per foot-run) including its own weight, given the following data:-

S.B.C. of soil = 20 tonnes/sq.m. (= 2 tons per sq.ft.)
Weight of soil = 1600 kg/cu.m. (= 100 lb. per c.ft.)
Angle of repose of soil = 30°

Consider 1 metre (one foot) length of wall.

Weight carried by the wall = 15 tonnes(= 6 tons)
Add weight of foundation @ 10% = 1.5 tonnes(= 0.6 tons)
Total load carried 16.5 tons. (= 6.6 tons)

$$\text{Area of foundation required} = \frac{\text{Weight}}{\text{S.B.C.}} = \frac{16.5}{20} = 0.85 \text{ sq.m.}$$

$$\frac{6.6}{2} = 3 \text{ sq.ft.}$$

Since length of wall considered is 1 m (1')

$$\therefore \text{Width required} = \frac{0.85}{1} = 0.85 \text{ m} = 85 \text{ cm.} \quad \frac{3.3}{1} = 3.3 \text{ feet} = 3'4''.$$

Since it is a two-brick wall i.e., 40 cm. (18") thick, the lowest footing must be 80 cm (36") thick and then as the concrete has to have an offset of at least 10 cm (4") on either side, minimum width of foundation bed would be 80 + 10 + 10 = 100 cm = 1 m. (36 + 4 + 4 = 44" or 3'8" say 3.75 feet).

$$\text{Then, pressure on soil } p = \frac{\text{Weight carried}}{\text{Area of foundation}}$$

$$= \frac{16.5}{1 \times 1} = 16.5 \text{ t / sq.m.} = \frac{6.6}{3.75 \times 1} = 1.76 \text{ tons/sft.}$$

$$\therefore \text{Depth of foundation required } d = \frac{16.5 \times 1000}{1600} \left(\frac{1-.5}{1+.5}\right)^2$$

$$= 1.15 \text{ m } (4.37 \text{ ft.})$$

The depth of concrete bed can be found by drawing 45° lines - Fig.27.

Example 2. What is the depth of foundation you would provide for an 18 inch square brick pier, 11.2 feet high, carrying a load of 12 tons, so that pressure on the soil may not exceed 1 ton per square foot? The weight of brick masonry and soil may be taken as 120 and 112 lb. per cft. respectively and the angle of repose of soil is 30°.

Weight carried by pier = 12 tons.

Weight of pier itself $= \frac{3}{2} \times \frac{3}{2} \times 11.2 \times \frac{120}{2240} = 1.35$ ton.

Add weight of foundation @ 10% $= \frac{13.35 \times 10}{100} = 1.34$ tons.

Total load carried $= 12.00 + 1.35 + 1.34 = 14.6$ tons.

Area of foundation required $= \frac{146}{1} = 14.6$ sq.ft.

or side of square foundation $= \sqrt{14.6} = 3.83$ ft. = 3'10".

For the 18" brick pier, lowest footing should be 36" or 3' and concrete bed 3' 8' square, and hence this 3'10" width is sufficient.

Pressure on soil $p = \frac{14.6}{3.83 \times 3.83} = 1$ ton per sq.ft.

$\therefore$ Depth of foundation required $d = \frac{1 \times 2240}{112} \frac{(1-0.5)^2}{(1+0.5)} = 2.22$ ft.

But minimum depth of 3'0" below ground prescribed should be used.

The thickness of concrete bed can then be found as before. See fig.28.

68. Improving Bearing Power of Soft Soils

Soft soils may be helped to bear heavier loads by

(1) Increasing the depth of foundation.

(2) Hand packing and ramming rubble, broken stone, gravel or sand in the trenches.

(3) Draining the sub soil properly.

(4) Compacting the soils by boring holes in the soft soil and filling them with sand or driving in short piles at intervals.

69. Methods of Securing Safe Foundation in Soft Soils.

(1) In soils not having a uniform resistance, the structure may be supported on a concrete bed below the entire structure, with steel girders or bars embedded.

(2) In soils overlying hard stratum beneath pier, pile or well foundations may be used.

(3) In soft soils of great depth, by using R.C.C. raft or extended footing foundations.

(4) When loads are concentrated by a series of piers or pilasters at intervals, their foundations may be connected by inverted arches which serve to distribute the pressure along the whole length of the foundations

70. Setting out or Ground Trenching

1. First the centre-lines of the main walls forming the biggest rectangle is laid on ground by driving pegs and streng hing strings across them, and the two diagonals checked, which should be equal. Then the intermediate walls are laid out by their centre lines. By this method of working from the whole to part, any errors can be easily detected.

2. These pegs must be driven well beyond the lines of excavation and in prolongations of the centre-lines (Fig.29). In important intricate works, masonry pillars may be built in place of pegs. On tops of these, grooves are cut or nails driven to indicate the exact position of the lines.

3. Lines for excavating foundation trenches may now be scored out on ground with a pick-axe, and excavation started.

4. For setting out a culvert or bridge, the first line to be laid is the centre-line of the roadway. All measurements are taken on this line and the work set out half on each side of it, parallel to the direction of the stream.

5. In addition, a brick pillar should be built on the sit its top plastered level, and its level fixed to serve as a benchmark to which all the levels of the building can be referred to.

71. Trenching

1. The earth excavated from the trenches should be dumped away from the edges of the trench, to facilitate work and prevent it from slipping in. The bottom of the trench should be absolutely level, which can be ensured by the use of a pair of sight rails and a set of boning rods.

72. Plinth

1. In the palins, the height of plinth should not be less than 30 to 50 cm (12" to 18") above ground level in dry localities. In marshy areas a high plinth may be provided to prevent dampness in the building.

Where the plinth is constructed in stone masonry in lime or cement mortar, it is usual to finish it with a plinth slab 8 to 10 cm (3 to 4 in.) thick (either of stone or of cement concrete 1:3:6). Where the footings are of brickwork, the plinth course may be a 5 cm (2") cement concrete slab or built of brick-on-edge in cement mortar 1:3, Fig.24.

3. The plinth course is projected slightly on the outside to throw off rain water and also to improve the appearance of the building.

4. Steps:- The front steps may have a rise of 15 to 20 cm. (6 to 8 in) and a tread of 20 to 30 cm (8 to 12 in).

5. In Black Cotton soil, it is advisable to remove the soil within the plinth to a depth of 60 to 100 cm (2' to 3') and refill the space with good soil of sandy nature or gravel. Otherwise the black soil is likely to expand and ruin the floor.

73. precautions against White Ants

1. Any termite mounds in the area should be dug out until the queen ants are destroyed, before starting the construction of the building. In addition one of the following methods may be employed to prevent ants entering the building:-

(1) A 10 cm (3") layer of fine sand below the concrete or brick flooring.

(2) A 1 cm (½ inch) layer of asphalt at plinth level.

(3) A layer of sand mixed with 1 litre of hot coal tar per sq.m. (2 gallons per 100 sq.ft.) of floor below the floor concrete.

(4) 25g of $CuSO_4$ added to 1 litre (1 lb for 4 gal) of water to be mixed with mortar in concrete or masonry.

(5) Yellow arsenic mixed with concrete of floor, mortar of brick-work and masonry in plinth in the following proportions--
600 g (4 lb) of arsenic per cu.m (100 cft) of concrete.
75 g (½ lb) of arsenic per cu.m (100 cft) of masonry.

(6) An extract made by crushing the leaves of the shrub Adhatoda vasica in water.

74. Damp-Proof Courses

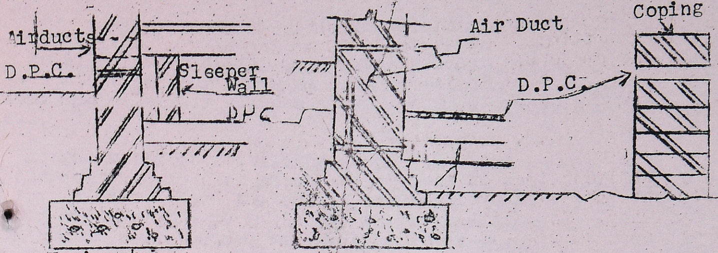
1. In damp sites, dampness rising from ground can be prevented by a damp-proof course at plinth level; damp coming in through the walls may be checked by rendering the outside of wall by a rich cement-sand (1:3) plaster, or by constructing the hollow walls Fig.30; dampness percolating from above can be prevented by a damp-proof course immediately below the cornice course Fig.31.

2. The damp proof course may consist of

(1) Two courses of slate set in cement mortar 1:3, with joints suitably staggered.

(2) A layer of hot asphalt 12 mm (½ in.) thick, sheet lead and bitumen damp-proof courses may be used both vertically and horizontally.

(3) Fine cement concrete 1:2:4 or cement mortar 1:2 about 12 mm (½ in) thick, may also be used as effective dam proof courses.


Airducts
D.P.C.
Sleeper Wall
DPC
Air Duct
Coping
D.P.C.

Horizontal

Vertical

Fig. 31. DAMP PROOF COURSES.

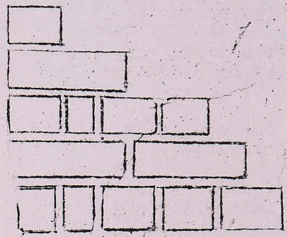


Fig. 32: RACKING OR STEPPING.

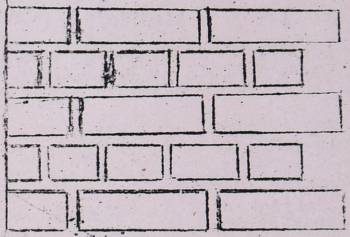


Fig. 33. TOOTHING

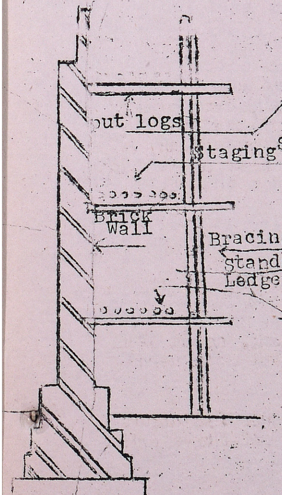

Put logs
Staging
Brick Wall
Bracing
Standard
Ledger

Fig. 34: BRICK LAYER'S SCAFFOLDING.

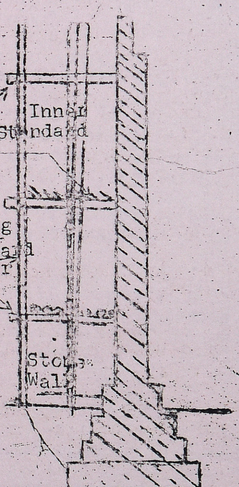

Inner Standard
Stone Wall

Fig. 35 MASON'S SCAFFOLDING.

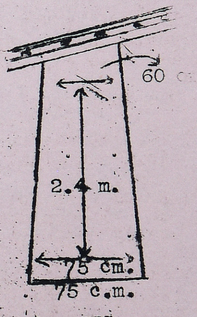

60 c
2.4 m.
75 cm.
75 c.m.

Fig.36 SEC OF A MUD WALL

SECTION 18. WALLS

75. General

1. Stone, when easily procurable locally, forms the strongest and most durable building material for walls. But bricks, bein small and uniformly sized blocks, are more easily handled and laid.

2. The walls of a building should be built up uniformly throughout and no part should be allowed to rise more than a metre (3 feet) above the rest: otherwise there may be irregular settlement. If it is absolutely necessary to raise a portion of a wall above the rest, the end should be built up in steps (Fig.32) to which the rest of the wall may be joined later.

3. Walls under construction must be kept constantly wet until the mortar has completely set; the stones or bricks must be soaked in water before use. At the end of the day's work, a little edge of mortar is built on top of the wall to form shallow basing and kept filled with water, until work commences next day.

4. If it is intended to add to the building at a future date, stones or bricks are left projecting from alternate courses of those walls which are to be extended--known as toothing (Fig.33). When a new wall is built, the end near the old wall is also toothed and the open joint left till the new wall also settles. Then bonding blocks connecting new and old work are introduced.

76. Thickness of Walls

1. All brick walls under 4 metres (12') high may have a thickness of not less than 19 cm (8½"). External walls may however be 29 cm (13") thick.

2. All brick walls which are over 4 m (12') but under 7 m (25') in height shall be 19 cm (8½ in) thick throughout, if their unsupported length does not exceed 10 m (30'); if they are longer than 10 m (30') then the lower storey wall may be 29 cm (13") thick and the rest shall be 19 cm (8½") thick. Inner partition walls which do not carry roof load can be 8 cm (4½") or at the most 19 cm (8") thick.

3. Rubble masonry walls will have to be at least 35 to 40 cm (15") thick to avoid the heavy expense of dressing all the stones to suit.

4. No wall should be built longer than 15 m (45') without being stiffened by cross-walls or buttresses. These buttresses should be made twice the thickness of the wall and should be provided under each roof truss or roof or floor girder to take the thrust.

77. Scaffolding

1. For brick walls, thick bamboos or round poles are erected vertically about a metre (3 to 4 feet) from face of wall and spaced 2 metres (5 or 6 feet) apart, Fig. 34; horizontal

bamboos are tied to these at about 2 metres (5 or 6 feet) vertical intervals, the ends of which are inserted in holes left in place of a header in the wall. Bamboos or planks are placed on these cross-poles for workmen to stand upon, when the work rises beyond their reach.

2. Scaffolding for masonry walls are not supported in the wall, but are made with two rows of vertical posts connected by cross-poles, so as to stand independently of the wall, and thus prevent appearance of patchwork in the unplastered surface Fig.35.

78. Mud walls

1. Mud walls may be built in two ways. Earth suitable for brick-making is dug out, weathered and tempered with the addition of water to make it into a stiff paste, moulded into bricks, sundried, and then set into a wall with mud mortar.

2. Alternatively, lumps of mud paste are packed together into the wall and consolidated by pressing in. The sides of the walls should be given a slight batter for stability - 1 in 30, with a minimum thickness of 60 cm (2') at the top Fig. 36. The upper surface of the wall should never be allowed to become dry while building is in progress. When finished, the surface is given a coating of mud plaster and leeping as specified under plastering.

3. These mud walls generally carry a light roof of thatching, though country tiled roofs are also common. Tops of walls, when exposed, should be given a protective layer of tiles or burnt bricks set in lime mortar to protect them against rain-water.

79. Mat walls

1. Mat walls are usually made of split bamboos interlaced so as to form a continuous surface, and fastened to the frame-work of the house by strings. The framing consists of 8 x 8 cm (3" x 3") scantlings or stout bamboos, on which the matting is placed and nailed to the frame-work through covering strips called zalees, about 8 x 1 cm (3" x ½") boarding or bamboo strips. The matting may be single, or double but placed close together.

80. Corrugated G.I. Sheet Wallings

G.I. sheet walling is sometimes used for cook houses and latrines. Sheetings of 22 to 26 guage are screwed to a framework of 8 x 8 cm (3" x 3") scantling, with G.I. screw 5 cm (2" long, a lead washer being used under the head. The side lap should be at least one corrugation and the end lap at least 8 cm (3").

81. Wooden Walls

1. These a-re generally used only in the hills and cold climates and rarely in the plains.

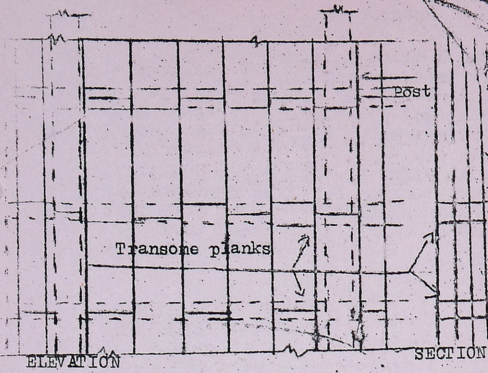

Post
Transome planks
ELEVATION
SECTION

Fig: 37: FLUSH BOARDING

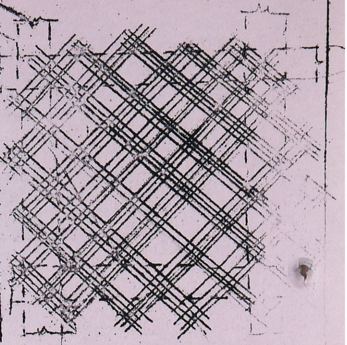


Fig: 39: WOODEN TRELLIS WALL

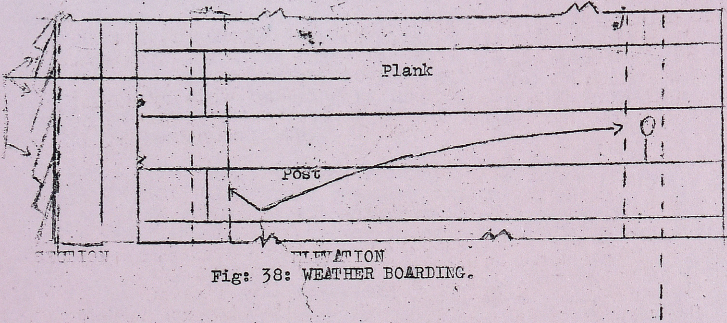

Plank
Post
SECTION
ELEVATION

Fig: 38: WEATHER BOARDING.

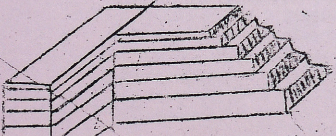


Fig: 40: BUILDING A BRICK WALL.

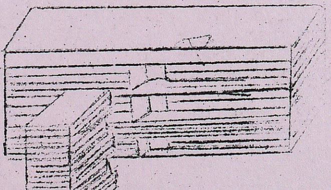
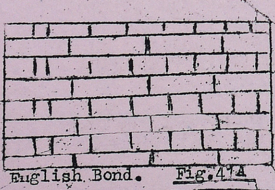
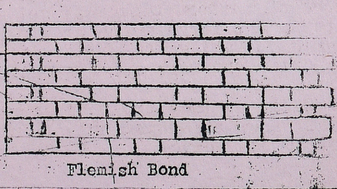


Fig.41: BLOCK BONDING



English Bond. Fig.41A



Flemish Bond

2. Flush Boarding:- This is the cheapest form of wood walling made of 2 to 4 cm (1 to $1\frac{1}{2}$") boarding usually placed vertically, with rebated or tongued and grooved joints, or butt joints, closed on the outside with small battens 5 cm (2" wide, Fig.27. The planks are nailed to a light framework of scantling generally 8 x 10 cm (3" x 4") placed horizontally at 1 m (3') vertical interval intervals and connected directly to house posts. The planks should be sawn to such lengths that the joints in adjacent planks will come alternately and immediately over a support. This is generally used only for interior walls or partitions.

3. Weather Boarding:- A good weather-proof wood walling may be made by 2 to 3 cm ($\frac{3}{4}$ to 1") planks, about 20 cm (8") wide, laid horizontally with an over-lap of 4 cm ($1\frac{1}{2}$") Fig.38. The planks are nailed to vertical posts 10 x 8 cm (4" x 3") spaced 1 to 2 m (3 to 6') apart. Proper weather-boarding should be cut tappering in cross-section and the thicker edge is placed downwa-rds.

4. Trellis Work: This is used mainly for verandahs. It is made of battens 4 x 2 cm ($1\frac{1}{2}$" x $\frac{1}{2}$") diagonally at 45°, the spaces being 4 cm ($1\frac{1}{2}$") squares (Fig.39). The battens are secured at the ends nailed to wooden posts to the house posts by nails and also nailed to each other at 1 m (3') intervals. The edges should be finished off with a batten all round on both sides.

SECTION 19. BRICKWORK

82. General

1. All walls of a building should be built up simultaneously with the bed joints made normal to the direction of load--horizontal in walls and columns, normal to centre line in arches, and normal to the battered face in retaining and breast walls. The corners or ends of walls are first built to a height of about 1 metre (2 to 3 feet), the angle bricks being carefully plumbed on both faces, and stepping the base of the corner along both walls. The intervening portion of the wall is then built up, being kept level and straight, by building the upper edge of the courses to a string strained between the two corners, Fig.40.

2. All iron fixtures, wood blocks, pipes, outlets for water, etc., should, as far as possible, be built into the work as it proceeds.

3. No broken, cracked or under-burnt bricks may be used. All bricks must be completely soaked in water before being used, and the mortar must be of proportions specified. All joints must be of uniform thickness not exceeding 1 cm ($\frac{3}{8}$"); the joints in the faces which are to be pointed or plastered should be raked out while the mortar is still green i.e., within 24 hours after the work is constructed.

4. Walls as they progress should be kept thoroughly wetted on their face and tops, and all new work should be kept wet for at least 7 days.

5. All bricks-work should be laid in "English Bond" unless otherwise specified. No half bricks or bats may be used, except where necessary to complete the bond.

6. For joining a new cross-wall to an old main wall, a number of rectangular recesses are cut in the main wall, equal in width to the thickness of the cross-wall, 3 courses in height and 10 cm (4½ in.) deep, a space of three courses being left alternately--Fig.41. The new cross-wall is then bounded into the recesses with cement mortar to avoid any settlement.

7. In Projecting courses of brick-work in footings, corbels, plinth and string courses, no projection should exceed the thickness of the wall, and each course should not project more than 5 cm (2¼"). Headers only must be used in these courses.

83. Bonds

1. The English Bond consists of one course of headers and one of stretchers alternately, and may be laid out as follows:-

In walls of thickness which is multiple of 20 cm (9"), the same course will show either stretchers or headers on both back and front elevations.

In walls of thickness which is an odd multiple of 10 cm (4½"), the same course will show either stretchers in front and headers at back, or headers in front and stretchers at back.

2. Fig.42 to 46 show the plans of two successive courses of brick-work in piers at corners, junctions, intersections and jambs of walls in commonly used 20 and 30 cm (9" and 13:") brick-work in English Bond.

84. Reinforced Brick Walls

1. Strong partitions may be built economically, half-brick thick, reinforced with hoop-iron. Only first class brick and cement mortar 1:2 should be used. The reinforcement will consist of two strips of hoop-iron, 12 to 20 guage, laid in every second course and placed near either edge of the wall, where the reinforcement is not logn enough, it may be lapped 50 cm (18") or revetted on to make a continuous strip. At either end of the wall, 5 cm (2") of the hoop-iron will be bent up or down so as to get a firm grip. At corners the hoop iron may be bent as required.

2. It must lie flat on the mortar and care must be taken that it is everywhere embedded in the mortar and not exposed.

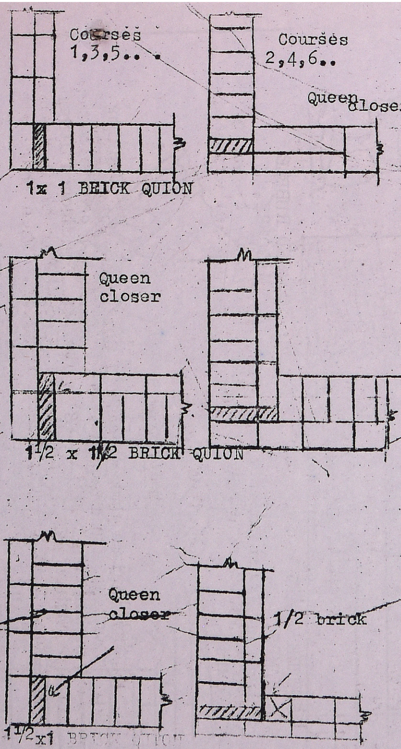
SECTION 20. MASONRY

85. General

1. The general principles specified for brick-work apply with equal importance to masonry-work. As far as possible the courses must be built at right angles to the direction of the load. All stratified stones should be placed with their natural bed at right angles to the direction of loads. When there are

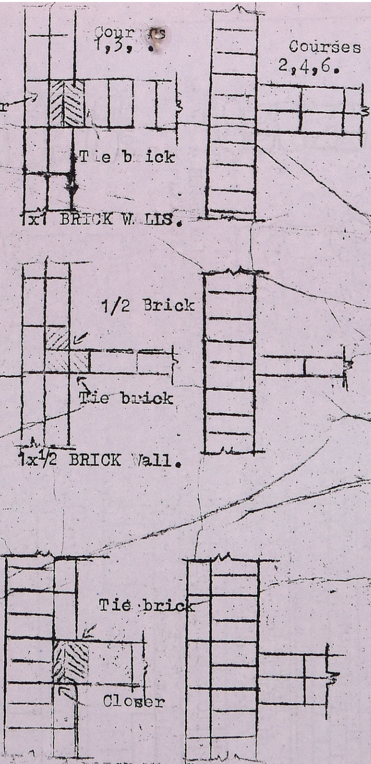
PLATE: 7

TO FACE PAGE 44.


Courses 1,3,5..
Courses 2,4,6..
Queen closer
1x 1 BRICK QUION
Queen closer
1½ x 1½ BRICK QUION
Queen closer
1/2 brick

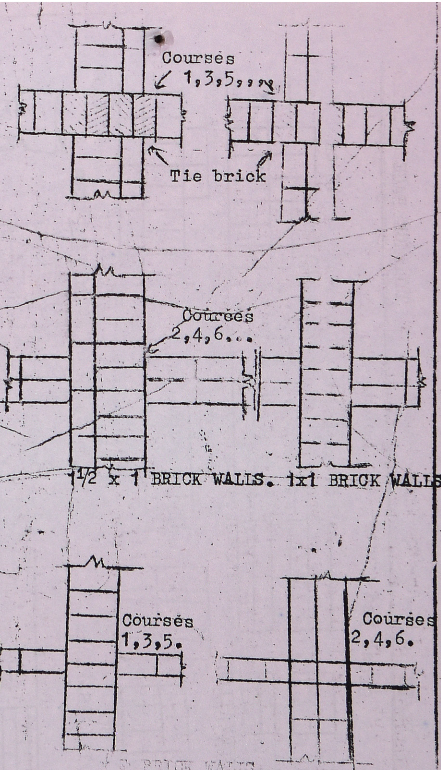
1½x1 BRICK QUION

Fig: 42: [illegible]


Courses 1,3, .
Tie brick
1x1 BRICK W. LLS.
Courses 2,4,6.
1/2 Brick
Tie brick
1x½ BRICK Wall.
Tie brick
Closer

1½ x 1 BRICK WALLS.

FIG.43: BONDS AT JUNCTIONS


Courses 1,3,5,,,,
Tie brick
Courses 2,4,6...
1½ x 1 BRICK WALLS.
1x1 BRICK WALLS
Courses 1,3,5.
Courses 2,4,6.

[illegible] BRICK WALLS,

[illegible] AT INTERSECTIONS.

PLATE 8:

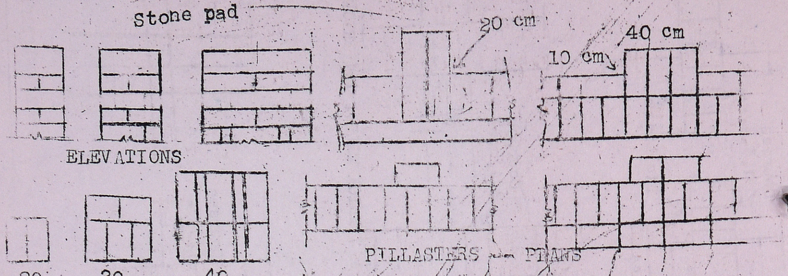

Stone pad
20 cm
40 cm
10 cm
ELEVATIONS
20
30
40
PILLARS-PLANS
PILLASTERS -- PLANS

Fig.45: PIERS & ATTACHED PIERS

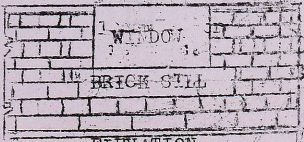

WINDOW
BRICK SILL
ELEVATION

Fig.51: Elevation of a window with brick sill.

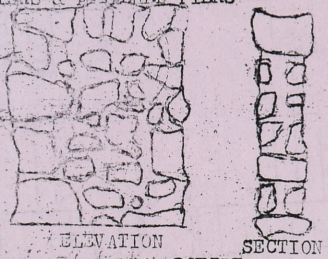

ELEVATION
SECTION

Fig.49: RANDOM RUBBLE MASONRY.

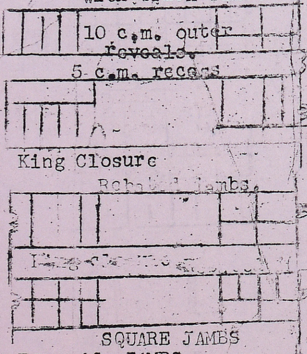

10 c.m. outer reveals.
5 c.m. recess
King Closure
Rebated Jambs.
SQUARE JAMBS

Fig: 46: JAMBS.

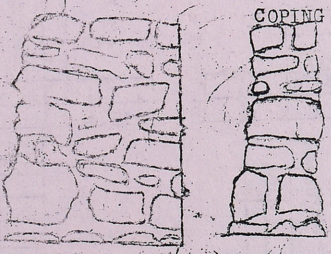


FIG.48: COURSED RUBBLE MASONRY.

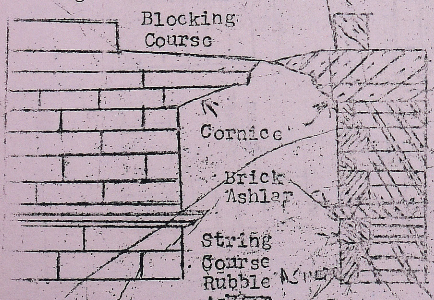

Blocking Course
Cornice
Brick Ashlar
String Course
Rubble Ashlar

Fig.47: BRICK & RUBBLE ASHLAR

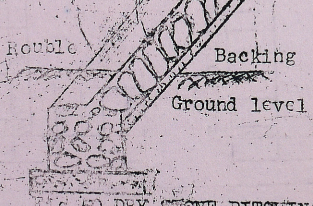

Rouble
Backing
Ground level

Fig.50 DRY STONE PITCHING

side thrusts and concrete loa-ds, they must be so arranged as to bring the resulting pressures to within the middle third of the base of the wall. Care should be taken that all joints and gaps between the irregular stones are completely filled with mortar and small stone pieces, and not left hollow. The surfaces of stones should be roughened by knocking off portions of rounded smooth surfaces and corners, before they are used in construction.

86. Ashlar Masonry

1. Ashlar masonry consists of squared blocks of stone dressed to a true face on at least 5 sides out of 6. In the case of through bond stones, the sixth side also must be tooled.

2. All joints should be perfectly horizontal and vertical, and never exceed 5 mm (1/8") in thickness.

3. The stones will be laid in regular courses not less than 30cm (12 inches) high and all courses will be of the same height, unless otherwise specified; no stone shall be less in width than its height, or its length less than twice its height. The stones must break joint on the face for at least half the height of the course, and the bond should be carefully maintained throughout the work.

87. Ashlar Facing

1. Ashlar masonry is very expensive and to reduce the cost, it is general practice to construct the walls in rubble, brick-work, or concrete, and face them with ashlar blocks to reduce the cost.

2. In this case, the height of ashlar courses should equal an exact number of courses of brick or rubble masonry including mortar joints, and the backing should be carried up simultaneously with the face work - Fig.47. Bond stones must run through the backing and must be inserted every 1.5 to 2 metres (5 to 6 feet) apart in each course, suitably staggered in alternate courses.

88. Coursed Rubble Masonry

1. Coursed rubble will be laid in courses which may vary in height as convenient, but no course should be less than 15 to 20 cm (6" to 8") thick and none will be thicker than any course below it - Fig.48.

2. Joints may be up to 1 cm (3/8") thick, and the vertical joints must be truly vertical and break joint on the face for at least half the height of the course.

3. Through bond stones must be provided every 1.5 metres (5 feet) in each course, suitably staggered in alternate courses.

4. The quoins must be of the same heights as the courses and formed of header stones 30 to 50 cm (12 to 18") long laid lengthwise alternately a long each face.

89. Random Rubble Masonry

1. The stones will be hammer-dressed, and laid at random, without being brought upto any level courses (Fig.49). Each is laid on its natural bed, a-nd wedged or pinned strongly into position by chips or stalls and mortar. The stones should be arranged to break joints as much as possible, through no attempt need be made to ensure verticality of the side joints, and the joints may be upto 2 cm (1") in thickness. At least one header or bond stone should be provided for every square metre (square yard) of face of the wall.

2. When the random rubble wall is roughly levelled upto form courses (30 to 50) (12 to 18") thick, it will be known as Random coursed rubble masonry.

90. Masonry in Mud Mortar

1. Random rubble masonry may be built in mud mortar as specified.

2. When foundations and plinth are built in mud mortar, a damp-proof course of lime or cement mortar should always be provided. The courses are generally levelled once at lintal or springing level of arches over doors and windows, and one intermediate course, laid in lime mortar.

3. Exposed faces of stone masonry in clay should be pointed with lime mortar on outside.

91. Dry Rubble Masonry

1. This is particularly suitable for retaining and breast walls, as in hill roads.

2. Through or bond stones should be provided in every course at 1.5 m (5") intervals, the bond stones or headers over-lapping at least 20 cm (6" to 8").

92. Dry stone pitching or Revetment

1. Stone for dry stone pitching should be not less than 25 cm long x 15 x 15 cm (10 in. long x 6" x 6"). The faces are roughly squared, and interstices filled in with chips as the work proceeds. The backing (Fig.50) is filled in simultaneously with the pitching.

SECTION 21 - SILLS AND LINTELS

93. Sills

1. Sills may be of stones, bricks, tiles, concrete or wood.

2. Brick sill:- Bricks are laid in cement mortar 1:3 and neatly pointed and plastered, giving a slight projection 2 cm (3/4") on the outside, and an equal projection under the jambs on each side - Fig.51.

3. Tiled Sills:- The flat tiles 15 to 30 cm (6 to 12") square are laid in cement mortar 1:2 over the brick-work in sills and projected 2 cm (3/4") on the outsides and under the jambs.

4. **Stone Sills:-** Stone slabs about 5 to 8 cm (3") thick may be laid over the bottom of the opening, projected outwards and weathered (slightly sloped down and throated underneath) to throw off rain-water, Fig.52.

5. **Concrete Sills:-** These are similar to stone sills and may be either precast slabs or cast insitu 1:3:6.

6. **Wooden Sills:-** These are used generally only in wooden structures, and the framing of the wall is adjusted to form the sill. They should not be used in brick or masonry structures, since they are liable to rot.

94. Lintels

1. **Lintels** are horizontal members of wood, brick, stone or reinforced concrete, spanning over door and window openings in walls to support the structure above. The widths of lintels should be equal to the thickness of the walls and the depth adjusted to suit.

2. **Loads on Lintels:-** When the wall above the lintel is high enough to contain an equilateral triangle with the clear opening as the base, the lintel will be designed to carry the weight of the material in this triangle, Fig.53. Otherwise, it should be designed to carry the portion of the roof or floor load also and will become heavy.

3. **Wooden Lintels:-** Structural timbers generally used are terminalia, teak, sal, deodar, chir, xylia, etc. Thickness of wood lintels may be made 12% of spean for spans upto 1.5 m (5') with a minimum thickness of 8 cm (3 inches). The width of lintel may be made up of 2 or 3 pieces bolted together, but each piece must be of the full depth required. These are used only in wooden structures of purely temporary buildings.

4. **Stone Lintels:-** A rough rule is to make the lintel 10 cm thick per metre (1" per foot) of span plus 5 cm(2") for spans upto 1.5 m (5'), subject to a minimum thickness of 8 cm (3").

5. **R.C.C. Lintels:-** These are cheaper and more reliable; this is rapidly replacing other materials, owing to its durability, strength, adaptability and fire-resistance. Precast lintels are more economical, as the same moulds can be used several times, and also the work over the lintels may be continued immediately. The usual mix adopted in 1:2:4, with 2 cm (3/4") broken stone aggregate. Fig.54 shows sketches of an R.C.C. lintel, and the table below gives details of reinforcements for lintels upto 3 metres (9') span.

Clear Span S	Minim. Bearing B cm	Depth of Lint. D cm	Thickness of wall T cm	Hooked rods a No. Dia. mm	Hooked & cranked rods b No. Dia mm	Hanger rod e No. Dia mm	Stirr Dia.s ing. mm
1.0	10	10	10	2.10	-	2.10	6.30
1.25	15	10	20	2.10	1.10	2.10	"
			30	3.10	2.10	2.10	"
1.50	15	12	10	2.10	1.10	2.10	"
2.0	20	15	20	2.10	1.10	"	"
			30	3.10	2.10	"	"
2.5	25	20	10	2.12	1.12	"	"
3.0	30	25	20	2.12	1.12	"	"
			30	3.12	2.12	"	"
[illegible]	4½"	4½"	4½"	2.3/8"	-	2.1/4"	¼"-12"
[illegible]	6"	4½"	9	2-3/8	1-3/8"	2-1/4"	"
			13½	3-3/8	2-3/8	2-3/8"	"
[illegible]	6	5	4½	2-3/8	1-3/8	"	"
[illegible]	9	6	9	2-3/8	1-3/8	"	"
			13½	3-3/8	2-3/8	"	"
8	9	8	4½	2-1/2	1-1/2	"	"
9	12	9	9	2-1/2	1-1/2	"	"
			13½	3-1/2	2-1/2	"	"

6. Reinforced Brickwork Lintels:- The bricks used must be sound and well-burnt and set in cement mortar 1:3 to which 10% of slaked lime is added.

The reinforcement generally used is 12 mm (½") dia. mild steel rods placed near the bottom of the vertical joints in the brick-work which is built with all bricks-on-end (i.e. 10 cm (3") face x 20 cm (9") high flat arch) along intrados 6 mm (¼") dia. stirrups may be used in the bed joints after every third vertical joint.

Laying:- After placing the centering and reinforcing rods in position the bricks of the lintels are laid working from each end towards the centre), as also the stirrups, care being taken that the continuous longitudinal joint is filled with mortar for the lower 5cm (2 inches) only. The top rod is inserted and pressed down into position and the continuous vertical joint is then filled with grout from the top. Pointing or plastering will complete the lintel.

The number and size of bars vary with the span and loading. 2 rods 12 mm (½") dia may be used in a 30 cm (13½") brick - lintel upto 2.5 m (8') span, and 2 Nos. 6 mm (¼") dia, may be used placed one above the other in the central longitudinal joint of a 20cm(9") thick lintel upto 2.5 m (8') span. In either case 6 mm(¼") stirrups should be bedded in every third vertical joint.

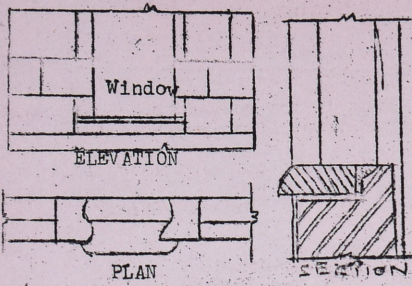

Window
ELEVATION
PLAN
SECTION

Fig. 52: STONE STILL.

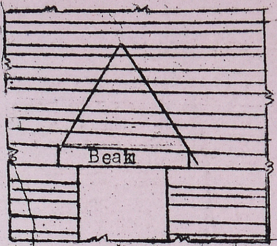


Fig:53: DESIGN LOAD ON LINTELS.

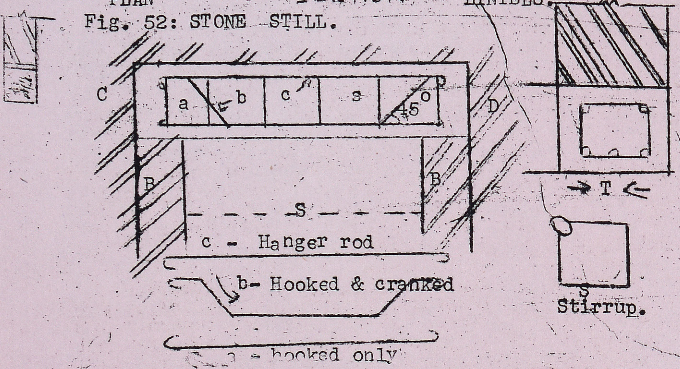

C
a
b
c
s
45°
D
B
B
S
c - Hanger rod
b- Hooked & cranked
a - hooked only
D
D
T
S
Stirrup.

Fig. 54: R.C.C. Lintel Details.

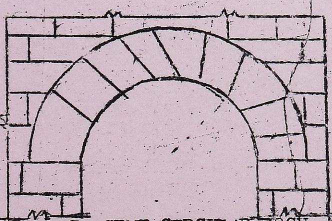


Fig.57: SEMI-CIRCULAR ARCH

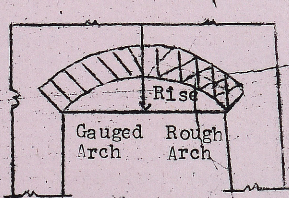

Rise
Gauged Arch
Rough Arch

Fig: 55 & 56: SEGMENTAL ARCHES

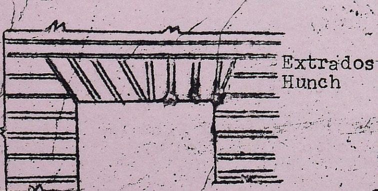

Extrados
Hunch

Fig 59: FLAT ARCH.

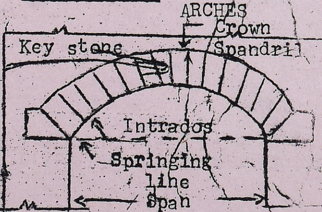

Crown
Key stone
Spandril
Intrados
Springing line
Span

Fig:58: SEGMENTAL ARCH

SECTION 22. ARCHES

95. Uses in Building

Arches may be used:

(i) to span door and window openings.
(ii) to span spaces between columns in the verandahs.
(iii) to support the fire places in front of chimney-breasts-trimmer arches.
(iv) in relieving arches over wooden or stone lintels or flat brick arches.
(v) in inverted arches to distribute the loads uniformly over the foundation.

96. Classification of Arches

1. Guaged arches are those in which the stone and brick voussoirs are cut to required wedge-shapes so that the mortar joints are uniformly thick, Fig.55. The arch is laid out to full scale on a template and each voussoir and joint marked on it. The bricks or stones are then gauged to shape and size before being used in the arch.

2. Rough arches are those built out of common bricks or st the mortar joints increasing in thickness from the intrados to extrados of arch to give the necessary shape, Fig.56. These are cheaper and used when the work is to be plastered, or in trimmer, relieving and inverted arches.

3. Based on shape, we may have semicircular (Fir.57), segmental (Fig.58), flat (Fig.59), elliptical, parabolic, gothic, etc. arches, of which the first two are the most common. Even here, the segmental arch is better balanced structurally, and the one having a rise of ¼ span is most generally used.

4. Flat arches: Flat arches are generally used to span door and window openings where the work is to be pointed, and for fire-place openings. This type of arch is not very strong and must be limited to spans upto 1 metre (3 to 4 feet), unless these are strengthened by rods or flats m.s., or relieving arches.

These should be given a slight camber by providing a rise of 1 cm per metre ($\frac{1}{8}$" per foot) of span to avoid the appearance of sagging. The angle of skew-back is generally 60°. The extrados should be made to coincide with a horizontal joint of the adjacent walling to avoid a split course; it is better if the intrados comes midway up a course, since it will be easy to cut the skew-back brick.

5. As a rough rule the thickness of arch rings in buildings may be as follows:-

Span	upto 1 m (4 ft)	1 to 3 m (4' - 10')	3 to 10 m (10'-30')
Thickness	1 brick	1½ bricks	2 bricks

6. The thickness t of arch rings may be found from the following formula:- If R is the radius of the arch.

		in metres	in feet
For segmental arches	Single arch :	$t = \sqrt{.04 R}$ m	$t = \sqrt{0.12 R}$ ft.
	for an archade :	$t = \sqrt{.06 R}$ m	$t = \sqrt{0.17 R}$ ft
For semi-circular arches:	Single arch :	$t = \sqrt{.07 R}$ m	$t = \sqrt{0.20 R}$ ft
	an archade :	$t = \sqrt{.08 R}$ m	$t = \sqrt{0.25 R}$ ft

97. Construction

1. Before the building of an arch is commenced, the skew-backs and all the bricks or stones for the arch should be laid out on the template and passed by a responsible officer.

2. The voussories are built up commencing from each skew-back towards the crown, where the key stone is driven into position by a wooden mallet.

3. In gauged arches, each voussoir is cut true to shape as per template, and then a groove 2 cm (1") wide and 1 cm (1/2") deep is cut on each bed surface to serve as a key to the mortar; the side of voussoir is dipped in putty and pressed against the previously laid voussoir and rubbed into position; when all the voussoirs are laid in position and the key-stone driven in, cement grout is poured into the joggles formed by the bed-grooves.

4. Lime mortar for brick arches should be specially ground fine. No joint should be thicker than 1 cm (3/8"), and all joints must be of the same thickness, bed joints being exactly radical.

98. Centering

1. For arches over door and window openings, a cheap method of centering is to build a pillar of brick in mud by the side of the jamb, and placing strong planks or rough poles on their top, Fig.60; brickwork set in mud are laid on top of these planks to the shape of the intrados, and exact shape is obtained by mud plastering on top. This is very cheap since all the bricks can be used up later.

2. For the arches oveer verandhah columns, bamboo or wooden props may be used, over which wooden centering frames are supported with double wooden wedges, to awsist in easing the centering before striking it. Fig.61.

3. If an arch is rapidly built, and the key-stone driven before the mortar in the joints has set, the centres may be struck immediately, but when there is any doubt, it is better to leave the centering in position for at least 7 days, and the masonry at the haunches must be built up before the centering is struck.

4. The joints must be filled flush and smooth as work proceeds, but when pointing and plastering is to be done, the joints must be raked within 24 hours.

PLATE 10.

TO FACE PAGE 51.

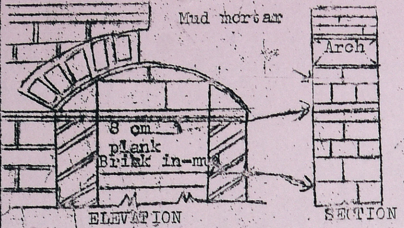

Mud mortar
8 cm.
plank
Brick in-mud
Arch
ELEVATION
SECTION

Fig: 60: CENTERING FOR SMALL ARCHES

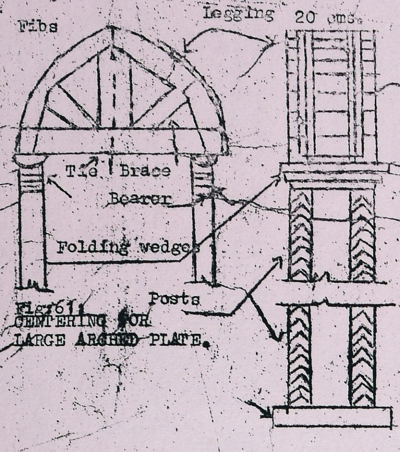

Legging
20 cms.
Fibs
Tie
Brace
Bearer
Folding wedges
Posts

Fig:61: CENTERING FOR LARGE ARCHED PLATE.

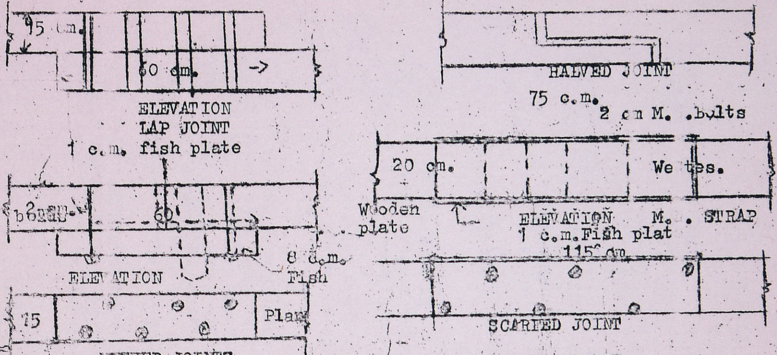

15 cm.
60 cm.
ELEVATION
LAP JOINT
1 c.m. fish plate
60
ELEVATION
8 c.m.
Fish
15
Plan
FISHED JOINTS
HALVED JOINT
75 c.m.
2 cm M. bolts
20 cm.
We tes.
Wooden
plate
ELEVATION
M. STRAP
1 c.m. Fish plat
115 cm.
SCARFED JOINT

Fig:62: LENGTHENIN JOINTS

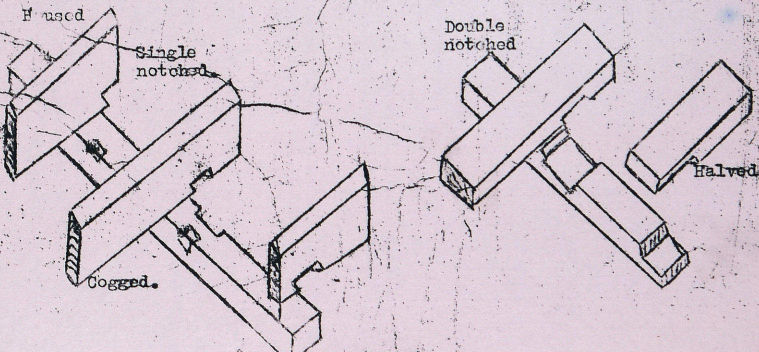
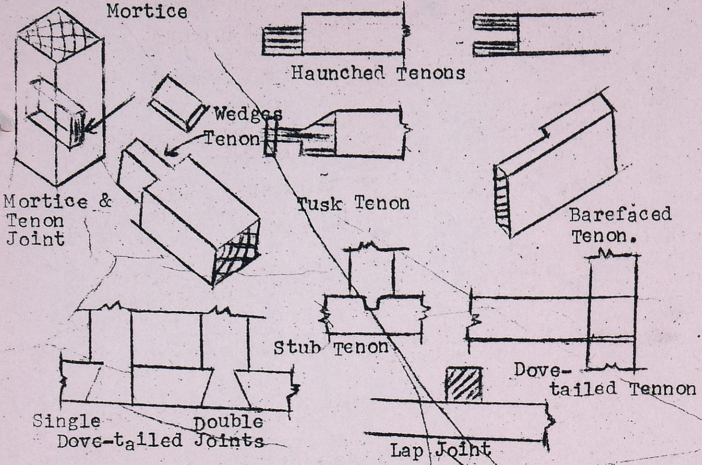

Housed
Single
notched.
Cogged.
Double
notched
Halved.

Fig: 63: BEARING JOINTS


Mortice
Haunched Tenons
Wedges
Tenon
Mortice & Tenon Joint
Tusk Tenon
Barefaced Tenon.
Stub Tenon
Dove-tailed Tennon
Single
Double
Dove-tailed Joints
Lap Joint

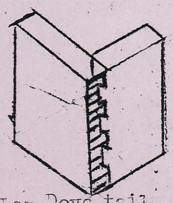

Lap Dove tail.

Fig:63-B BEARING JOINTS.

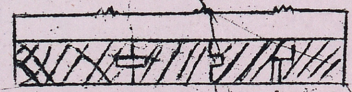

Edge groved and Tongued & Rebated shot filletted grooved.

Fig:64: BOARDING JOINTS

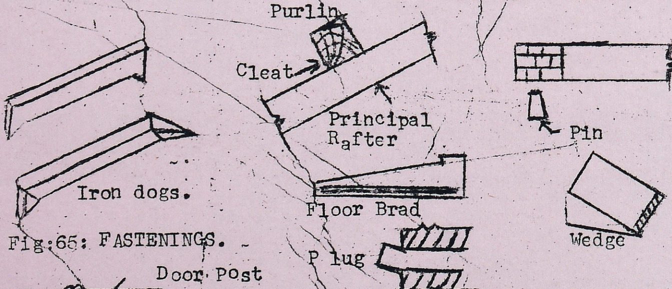

Purlin
Cleat
Principal Rafter
Pin
Iron dogs.
Floor Brad
Wedge
Plug

Fig:65: FASTENINGS.

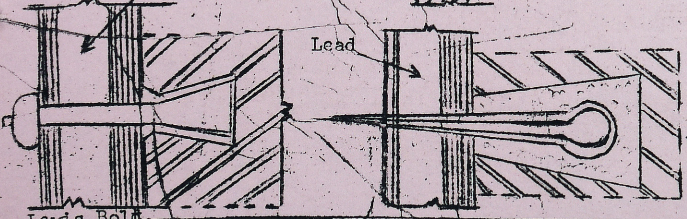

Door Post
Lead
Lewis Bolt.
Split Bill Posts.

Fig:66: FIXING DOOR

5. The arch-work must be kept wet for the least 7 days after completion.

SECTION 23. TIMBER, CARPENTRY AND JOINERY

99. Characteristics of a good Structural Timber

1. A good structural timber should be straight-grained, and free from large, loose or dead knots and sap wood.

2. The annual rings, should be even thickness, indicating uniform growth. Closer the rings, stronger will be the timber, and also a darker tinge indicates stronger timber.

3. Sound timber should be sweet smelling, and when planed, should have a firm, bright and silky lustre. (A disagreeable smell and wooly surface indicates decay).

4. In wood of a given species, the heavier ones are generally stronger and more lasting.

5. Only well-seasoned heart wood should be used in construction of buildings.

100. Different types of Timber Joints

1. For lengthening of beams and other members, lapped, halved, fished, (butt) and scarfed joints may be used, Fig.62.

For joining timbers at an angle, lapped, mortice and tenon, bridle, notched, cogged, housed, trenched, keyed, or dovetailed joint may be used Fig.63.

For joining boards in the same plane, edges-shot, tongued and grooved, grooved and filleted, rebated, dowelled, etc. joints may be used Fig.64.

2. The different types of fastening used are iron dogs, wooden cleats, bolts and nuts, straps, coach screws, wedges, pins and trenails, Fig.65. Lewis or rag bolts and split bills are often used as hold-fasts for fixing wood work against masonry or brick work, Fig.66.

3. Wooden plugs should be cut out of dry, straight-grained wood and driven into the hole for at least 5 cm (2 inches).

4. See also Art.125, Page 67.

SECTION 24. ROOFS

101. Roof Slopes

1. The Pitch of a roof is the ratio of its rise to span, and depends upon the climatic conditions of the area, nature of the roofing materials, and the rainfall or snow-fall in the locality. The following table shows the slopes suggested for various types of roof coverings generally adopted:-

Roof-Covering	Heavy Rainfall or snowfall or Hilly regions		Moderate Rainfall or Dry regions and in plains	
	Pitch	Slope	Pitch	Slope
1. Flat roofs	1/30-to 1/40	2^0 to $1\frac{1}{2}^0$	1/40 to 1/60	$1\frac{1}{2}^0$ to 1
2. Corrugated G.I. or Asbestos Cement Sheets.	1/3 to 1/4	$33\ 1/2^0$ to $26\ 1/3^0$	1/4 to 1/10	$26\ 1/2^0$ 11 1/4
3. Slates or shingles	1/2 to 1	45^0 to $33\frac{1}{2}^0$	1/4 to 4/5	$26\ 1/2^0$ 21 3/4
4. Plain or flat tiles i.e., Mangalore or Kanpur tiles.	1/3	$33\ 1/2^0$	1/4	$26\ 1/2^0$
5. Allahabad tiles, country tiles and thatch.	$\frac{1}{1.19}$	60^0	1/2	45^0

2. When a combination of two types of roof covering is used, like tiles or shingles over corregulated iron sheets, 'the roof is given the slope required for the flatter type.

102. Lean-to Roofs

1. Lean-to Roofs are roofs formed with one slope only, generally used for out-houses, Fig.67, sheds built against main walls of a building, Fig.68, or for verandahs, Fig.69. Spans up to 3 metres (8 or 10 feet) can be conveniently covered by this type. In sheds and out-houses, the common rafters can be connected to the wall plates, but for verandahs a post plate or bressumer will be used on tops of pillars or columns, to receive the feet of the rafters. The head and feet of the rafters will be fixed to the wall-plates or breasumers by birds-mouth joint.

2. The wall plate may be supported on the walls for independent outhouses, but for verandahs and attached sheds, a wall-plate may be supported on cut stone corbels, Fig.7, or milk steel brackets built into the wall 1 to 2 metres (3 to 6 apart Fig.71, or on a 10 cm ($4\frac{1}{2}$") corbel course projecti out of main wall, with mild steel straps 50 x 6 mm (2" x $\frac{1}{4}$") over the wall plate and built into the wall at 1 to 2 m (3 to 6') intervals to prevent displacement of the wall plate Fig.72 The junction of the roof with the wall should be made water-proof by laying a 2 cm ($\frac{3}{4}$") thick cement mortar 1:3 there.

3. The sizes of scantlings may be as shown under couple close roof below.

103. Couple Roof.

1. Couple Roofs are composed of rafters with their feet securely fixed to the wall-plates (by birds-mouth joint), and their heads butting against a ridge piece or against each other, or being halved and bolted together, Fig.73.

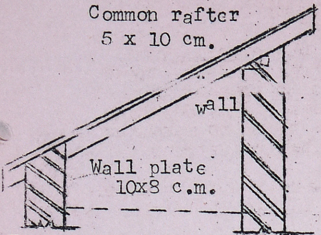

Common rafter
5 x 10 cm.
wall
Wall plate
10x8 c.m.

Fig:67: LEAN-TO ROOF OVER OUT HOUSE

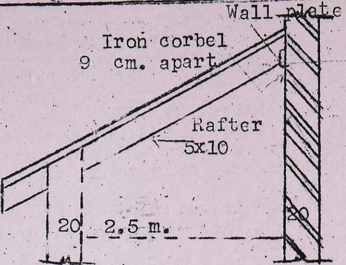

Wall plate
Iron corbel
9 cm. apart
Rafter
5x10
20
2.5 m.
20

Fig.68: ATTACHED SHED

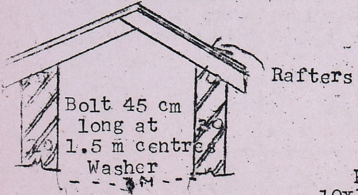

Rafters
Bolt 45 cm
long at
1.5 m centres
Washer
20
20

Fig.73: COUPLE ROOF

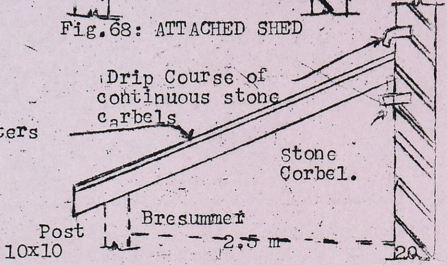
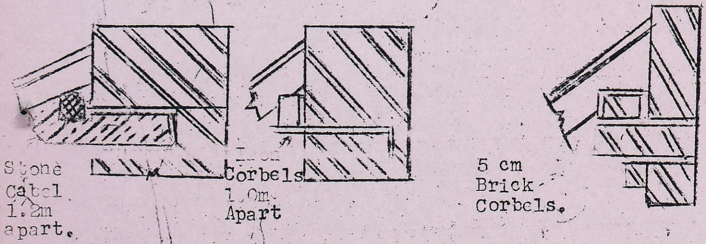

Drip Course of
continuous stone
carbels
Stone
Corbel.
Bresummer
Post
10x10
2.5 m
20

Fig.69: A VERANDAH ROOF


Stone
Cabel
1.2m
apart.
Iron
Corbels
1.0m
Apart
5 cm
Brick
Corbels.

Figs.70,71,72: METHODS OF FIXING W.P. TO MAIN WALLS

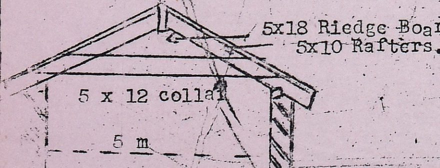

5x18 Riedge Boards
5x10 Rafters.
5 x 12 collar
5 m

Fig.74: COLLAR BEAM ROOF

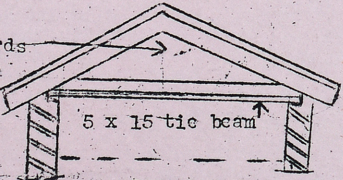

5 x 15 tie beam

Fig.75: COUPLE CLOSE ROOF

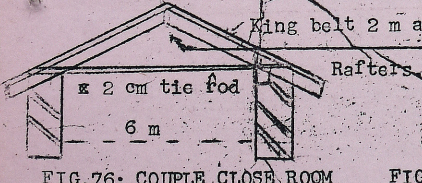

King belt 2 m apart
Rafters
2 cm tie rod
6 m

FIG.76: COUPLE CLOSE ROOM

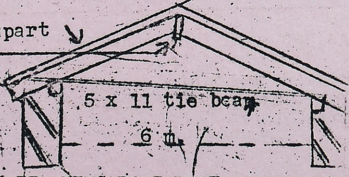

5 x 11 tie beam
6 m.

FIG:77: KING BOLT ROOF.

2. These are suitable for spans of 3 to 4 metres (10 to 12 feet) and scantlings given for couple-close roofs below may be used.

104. Collar Beam Roofs

1. In this type, each pair of rafters has a collar, a scantling similar to the rafters, fixed about half-way up the slope of the rafters, Fig.74. This tends to prevent the spread of the rafters, but it also produces a considerable bending stress. Care should therefore be taken to make the rafters sufficiently deep to resist this bending stress.

2. The collar is connected to the rafters either by simple lapping and 1 cm (3/8") dia bolts, or by dove-tail halving and spikes or bolts.

3. This can be used for spans 4 to 5 metres (12 to 16') and scantlings may be as shown under couple-close roofs below. These have the advantage of increasing the head-room available in the case of a couple-close roof.

105. Couple-close Roof

1. In this type, the feet of the rafters are tied by a tie-beam or a tie-rod to prevent the walls being thrust out, Fig. 75 & 76. In superior work the tie beam and the rafters are connected by a dove-tailed halved joint, but in ordinary work it is enough to lap them and spike or bolt them together with 1 cm ($\frac{3}{8}$") dia. bolts. The mild steel tie-rod 2 to 3 cm ($\frac{3}{8}$ to 1") dia may be flattened out at the end and spiked to the feet of the rafters.

2. These can be used for spans 4 to 6 metres (12 to 18 fee and scantlings for roofs with a pitch of $\frac{1}{4}$ span as given below may be used:-

Span from centre to centre of wallplates	Rafters	Ridge piece where used	Collar where used	Tie-Beam where used	Remarks
3m	5 cm x 8 cm	5 cm x 12 cm	5 cm x 8 cm	5 cm x 12 cm	Collar & Tie Beams used only if ceiling is to be provided. If these spans have a king-bolt the tie-beam depths may be halved
4 m	5 x 10	5 x 12	5 x 10	5 x 15	
12 ft.	2"x4"	2"x6"	2"x4"	2"x6"	
14 ft.	2 x 4½	2 x 6	2 x 4	2 x 7	
5 m	5 cm x 12 cm	5 cm x 18 cm	5 cm x 12 cm	5 cm x 20 cm	
6 m	5 x 15	5 x 8	.-	5 x 22	
16 ft	2"x5 "	2"x7"	2"x5"	2" x 8"	
18 ft	2 x 5½	2 x 7	-	2 x 9	

3. As the span increases, the tendency of the tie-beam is to sag. To prevent this, a scantling 8 x 15 cm (3" x 6") may be spiked in the centre and over the tie-beams, and supported by a king bolt from the ridge at intervals of about 2 metres (6') Fig.77.

4. The battens or reepers used for hanging the tiles are 5 x 3 to 4 x 2 cm (2" x 1" to 1½" x ¾") depending upon the spacing of rafters, and weight of roof-covering to be supported.

5. If sal or teak scantlings of sizes given in the above table are used, the trusses or common rafters may be spaced at 1.2 m (4") centres for a roof load of 100 $kg./m^2$ (20 lbs/sft) and 80 cm (32") centres for roof loads of 150 kg/m^2 (30 lbs/sft). If Deodar, Kail or Terminalias are used, the spacing should be reduced to 80 cm (32") and 60 cm (24") respectively. The maximum span for common rafters should not exceed 2.5 metres (8 feet).

6. Wall plates are generally 10 x 8 cm (4"x3"). They should be tarred or creosoted before being embeded in the wall and secured by 1.2 cm (½") dia anchor bolts 50 cm (18") long, at 1.5 m (5') centres with 10 x 10 x 1 cm (4" x 4" x ¾") m.s. plate washers Fig.73.

7. Jack rafters are similar to the common rafters but of shorter length used in hipped and valley ends of the roofs, between the hip-rafter and the eaves, or between the ridge-piece and the valley rafter respectively-Fig.78.

8. Eave Board is a timber plank 2 to 3 cm (1") thick x 15 to 25 cm (6 to 10") deep, fixed along the eave to cover the cut ends of the common rafters-Fig.74.

9. The hip rafter is the scantling along the corner, where two sloping roof surfaces meet forming an external angle of over 180°. It is generally 8 x 12 cm to 8 x 18 cm (3" x 5" to 3" x 7") Fig.78.

The Valley rafter is the scantling about 8 cm (3") wide x 12 to 18 cm (5 to 7") deep placed along the junction of two sloping roofs forming a valley--Fig.78.

The hips and valleys are formed at 45° to the eave line in plan--Fig.78.

10. Bressumers or post plates may be 8 x 12 to 10 x 15 cm (3" x 4½" to 4" x 6") for spans from 2 to 3 metres (6 to 10 ft.).

11. Trimming:- Where a chimney stack crosses a roof, the rafters have to be trimmed i.e., cut short and a frame-work has to be made around the chimney, to which the rafters can be fixed Fig.79. Care should be taken to prevent leakage at the junction by providing good flashing all round.

12. Wind Filling is the walling that is carried up between the common rafters to the underside of roof-covering Fig.74.

106. Double Rafter or Purlin Roofs

1. When the span for common rafters exceeds 2.5 metres (8') purlins are introduced bearing on the cross-walls or pillars to support the common rafters at not more than 2 to 2.5 m (6 to 8 feet) intervals Fig.80.

2. Joints in purlins and common rafters are best provided

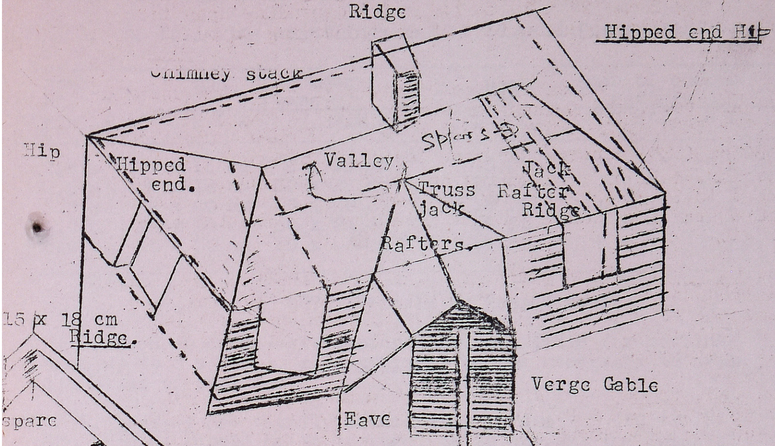

Ridge
Hipped end Hip
Chimney stack
Hip
Hipped end.
Valley
Spars
Truss jack
Jack Rafter Ridge
Rafters.
Verge Gable
Eave

Fig: 78: FIGURE SHOWING VARIOUS ROOF MEMBERS

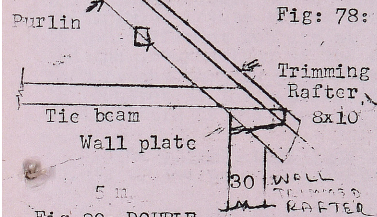

15 x 18 cm
Ridge.
spare
Purlin
Trimming Rafter 8x10
Tie beam
Wall plate
30
WALL TRIMMED RAFTER
5 m

Fig.80: DOUBLE Rafter or Purlin roof

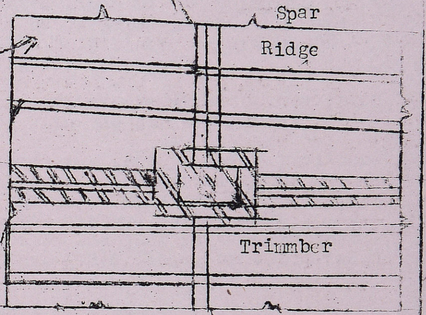

Spar
Ridge
Trimmber

Fig.78: TRIMMING AROUND CHIMNEY STACK.

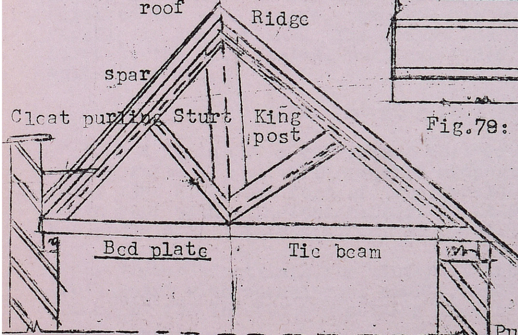

Ridge
spar
Cleat purling
Sturt
King post
Bed plate
Tie beam

FIG.81: THE KING POST TRUSS.

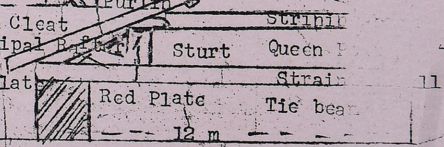

Spart
Ridge
Purlin
Cleat
Principal Rafter
Striping
Sturt
Queen P
Strain
11
Wall plate
Red Plate
Tie beam
12 m

Fig: 84: The UEEN POST TRUSS

over a wall support, over-lapped and bolted together; if the joint is to be outside the supports, they may be butted together with fish plates on either side and bolted.

3. The following scantlings may be adopted for purlins:-

Span of purlin	Span of common rafters		Span of purlin	Span of common rafters	
	2.0 m	2.5 m		6 ft.	8 ft.
2.5 m	8 x 15 cm	8 x 18 cm	8 ft.	3" x 6"	3" x 7"
3.0 m	8 x 18 cm	10 x 18 cm	10 ft.	3 x 7	4 x 7
3.5 m	8 x 20 cm	10 x 20 cm	12 ft.	4 x 6	4 x 8
4.0 m	10 x 20 cm	10 x 25 cm	14 ft.	4 x 8	6 x 8
5.0 m	15 x 20 cm	15 x 25 cm	16 ft.	6 x 8	6 x10

107. Tripple or Framed Roofs

1. When no cross-wall supports are available for purlins even up to 5 m (16'), roof trusses become necessary to avoid big sizes of purlins.

2. Trusses are usually spaced at 3 to 4 m (10 to 12'). The framing should be so arranged as to support the loads at the angular points of the triangles formed. The centre-line of the different members at a junction should meet at a point and the intersection of the centre lines of the principal rafters and the tie beam should be arranged immediately over the centres of the bearing (walls or pillars) or within the middle third of the support, Fig.81.

3. The correct positions for purlins are directly over the joints of the principal rafters with the struts, Fig.81.

4. The trusses or half-trusses are first placed in position, then the ridge piece. The wall plates are halved at the angles and bedded in mortar; the angle ties are framed and fixed to the wall plates, then the hip and valley rafters and finally to the purlins. The common and jack rafters are then fixed to the wall plates, purlins, ridge piece, or to hip and valley rafters.

108. The King Post Truss

1. 5 x 10 cm (2" x 4") is the most economical scantling for common rafters, and these require support at every 2.5 metres (8'). The king-post form of truss would therefore be suitable for a roof with principal rafters up to 5 metres (16') long or for spans 6 to 9 metres (20 to 30 feet).

2. Timber scantlings for king-post trusses, spaced 3 m (10') apart with normal roof slopes, and a roof load of 150 kg/m^2 (30 lb/sft) + a ceiling load of 35 kg/m^2 (7 lb/sft) are shown below:-

Span	Tie Beam cm x cm	Principal rafter cm x cm	King post cm x cm	Strut cm x cm	Remarks
6 m	8x12 (8x10)	8 x8	8 x 8	8 x 8	
7 m	10x12 (10x10)	10x10	10 x10	10 x10	
8 m	10x15 (10x12)	10x10	10 x10	10 x10	
9 m	10x18 (10x15)	10x12	10x10	10 x10	Figures in brack show sizes of T Beams when no ce ing is used.
20 ft.	3"x5" (3" x 4")	3"x3"	3"x3"	3"x3"	
24 ft.	4 x 5 (4 x 4)	4x4	4x4	4x4	
28 ft.	4 x 6 (4 x 5)	4x4	4x4	4x4	
30 ft.	4 x 7 (4 x 6)	4x5	4x4	4x4	

3. A 1.2 cm (½") dia king-bolt may be used in place of the king-post.

4. The nature of stresses in the members a re as follows:-

Compression: Principal rafters and struts
Tension : King posts and tie-beam without ceiling
Transverse or bending: Purlins and common rafters.
Bending and tension: Tie-beam with ceiling attached.

5. Joints:- Head of principal rafters are joined to the king-post by a shoulder and stump-tenon joint, being secured by two three-way m.s., straps 4 x 1 cm (1¾" x ⅜") one on each face of truss, using 1.2 cm (½") dia bolts Fig.82.

King-post and time beam are held together by a stump-tenon and a 2.2 cm (⅞") dia joint-bolt, but a gib and cotter arrangement would be better, Fig.82.

Feet of principal rafters and the tie-beam are secured by a bridle joint and a 2 cm (¾") dia heel bolt, or a 5 x 1 cm (2" x ⅜") heel strap and bolt, through the tie-beam. Fig.83.

The struts a re stump-tenoned into the under-side of the principal rafters and the shoulder at the foot of the king-post. Fig.82.

6. The purlins are cogged to a depth of 3 cm (1") over the back of principal rafter and are also supported by wooden cleats spiked or housed into the rafters on the lower side of the purlin. Fig.82.

7. The common rafters are notched on to the backs of the purlins, butted against the ridge board supported over the king-posts, and nailed to it at their heads and birds-mouthed on to the wall-plates at their feet.

8. Wall bearings:- The trusses must be anchored to the walls at each end with one 2 cm (¾") dia bolt, 50 cm (2') long and an 8 x 8 .6 cm (3"x3"x 1/4") plate washer with the end of tie beam resting on a cut stone or cement concrete (1:3:6) bed-plate, 15 cm (6") thick and 50 cm (18") long, Fig.81.

9. Camber: The tie-beam should be given a camber of 1/250 of span when the truss-members are being put together.

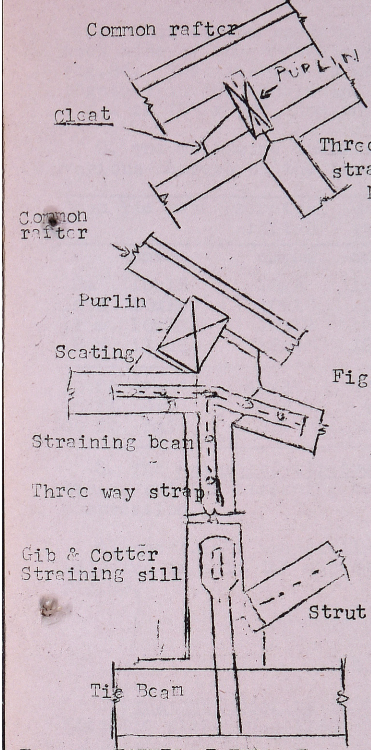

Common rafter
PURLIN
Cleat
Common rafter
Purlin
Seating
Straining beam
Three way strap
Gib & Cotter
Straining sill
Strut
Tie Beam

Fig.85: JOINTS AT ENDS OF QUEEN POST TRUSS.

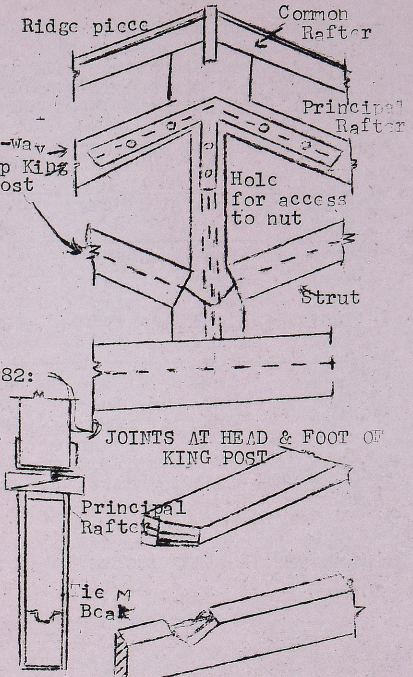

Ridge piece
Common
Rafter
Principal
Rafter
Three-way
strap King
post
Hole
for access
to nut
Strut
Principal
Rafter
Tie
Beam

Fig.82: JOINTS AT HEAD & FOOT OF KING POST

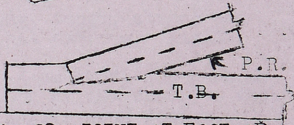


Fig.83: JOINT AT FOOT OF PRINCIPAL RAFTER.

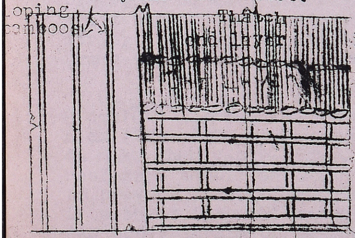

loping
camboos
Thatch
Good layer
Bamboo
Strips

Fig.86: THATCHED ROOF

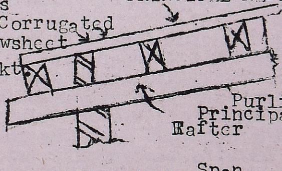

Corrugated
Screwsheet
J.bikt
Purlin
Principal
Rafter
Span

Fig:87: C.G.I. SHEET ROOF.

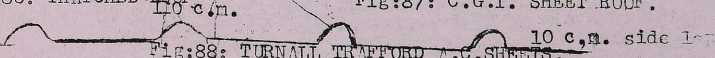

110 c.m.
10 c,m. side la

Fig:88: TURNALL TRAFFORD A.C.SHEETS.

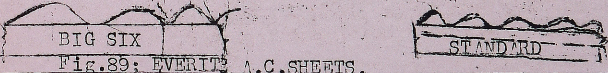

BIG SIX
STANDARD

Fig.89: EVERITE A.C.SHEETS.

10. If tie-beam is made in two pieces, they may be joined together with a fished joint--Fig.81.

109. The Queen Post Truss

1. This can be used to support a roof with two purlins on each side of the ridge. spans 9 to 12 metres (30 to 40'). Fig.84. The tie-beam is generally in two pieces butted together in the middle and secured by two m.s. fish plates 8 x 1 cm (3" x $\frac{3}{8}$"), one on each face, and 2 cm ($\frac{3}{4}$") dia bolts

2. The following table shows scantlings suitable for the various members of the truss:-

&

Span	Tie Beam	Principal rafter	Queen-post	strute	Straining	Straining Beam
	cmxcm	cmxcm	cmxcm	cmxcm	cmxcm	cmxcm
9m	10x15	10x8	10x12	10x8	10x12	10x5
10 m	10x18	10x10	10x12	10x8	10x12	10x5
11 m	10x18	10x12	10x12	10x8	10x15	10x5
12 m	12x18	12x15	12x15	12x8	12x15	12x5
30 ft	4"x6"	4"x3"	4"x5"	4"x3"	4"x5"	4"x2"
35 ft	4x7	4x5	4x5	4x3	4x5	4x2
40 ft	5x7	5x6	5x6	5x8	5x6	5x2

3. The nature of stresses are similar to those of king-post truss, and the straining beam and straining sill are also in compression.

4. The joints are similar to those in a king-post truss, adjusted to suit the directions of centre lines of the members. Fig.83.

SECTION 25. ROOF COVERING

110. Thatching

1. Thatched roofing is made of long, tough, strong and flexible grass on a frame-work of small bamboos. Fig.86.

2. The bamboo framing consists of 4 cm (1$\frac{1}{2}$") dia bamboos placed 30 cm (1') apart along the slope of the roof, to which split bamboos are fastened at right angles with good moonj string. A layer of bamboo matting can be laid over the frame-work (jafri) to make the inside of the room cleaner.

3. Thatch should be 15 to 25 cm (6 to 9") thick, laid in 8 cm (3") layers, the over-lap of each handful laid being 5 cm (2"). The ridges and hips must be carefully bound over to make them water-tight. Where chimneys pass through the roof care should be taken to provide proper flashings all ro to prevent leakage by introducing suitably bent galvanized iron sheet into the masonry of the chimney and between the two upper layers of thatch.

4. The pitch of the roof is generally 45°.

111. Country Tiled Roof

1. The tiles must be the best pot tiles, well burnt from good tempered clay, free from cracks and flaws-Fig.8 and 9.

2. Laying:- A strong network of bamboos is prepared similar to that used for thatching, over which the tiles may be laid single or double, as required. The first row of tiles near the eaves is set in mud or lime mortar, and in windly localities, they may be further secured by a hoop iron strap laid along the edge and tied down to the bamboos below. The lower layer is laid concave upward with wider end towards the ridge, fitting closely into one another. The second layer is then laid convex upwards with wider ends towards the cave, thus preventing the tiles from slipping down.

3. The ridges, eaves and hips should always be set in lime mortar.

112. Mangalore Tiled Roof

1. Tiles:- Tiles should be thoroughly well-burnt Magalor tiles, sound, of a uniform colour and size, giving a clear ringing sound when struck, and free from flaws, cracks, twists or any other defects, Fig.12 and 13.

2. Laying:- The guage for fixing the battens over common rafters varies for different makes of tiles; for the Basel Mission tiles (South Indian) the spacing is 32 cm (12½") centres, while for Kanpur tiles, it is 35 cm (13¾"). The battens are nailed to the upper surfa-ce of the common rafters at the required spacing and at right angles to their directions.

3. The lowest or the eaves batten should have an extra depth, of 2 cm (¾") to make the roof slope even and continuous from ridge to eaves, and should be spaced 25 cm (10") from the one immediately above to support the end tile.

4. The tiles will be laid square and properly fitting one another, with the catches resting fully on the battens and in the notches of tiles.

5. The ridge and hip tiles will be set in lime mortar, and the eave tiles will be screwed down to the eaves batten or otherwise secured against winds, except when bedded in masonry. Tiles at gable ends must be similarly secured to the battens below.

6. Special ridge and hip tiles and ventilating tiles are available for use either on slopes or in ridges.

113. Allahabad Tiling

1. Tiles:- All tiles must be thoroughly well burnt, sound of uniform colour and size, and free from flaws, twists or other defect, ringing clearly when struck, Fig.14 and 15.

2. Types: Tiling may be single or double.

Single tiling consists of a layer of flat tiles laid on battens, the side joints of every two adjacent tiles being covered with semi-cylindrical tiles.

Double tiling consists of a lower layer of flat tiles laid on battens, the side joints of every two adjacent tiles being covered with semi-hexagonal tiles. Over these will be laid another layer of flat tiles, the side joints of adjacent tiles being covered with semi-cylindrical tiles as before.

3. Laying:- All tiles must fit closely and well, the moulded niche at the lower end of each flat tile fitting completely on to the head of the next tile below it, and the buttons at the upper end must have a firm hold on the wood battens, nailed at 30 cm (1 foot) intervals on the common rafters, below. Each semi-hexagonal tile must fit exactly in its position, both semi-hexagonal tile under it and also into the beds specially formed in the upper part of the next semi-hexagonal tile below it.

4. The upper flat tiles must fit in the positions made for them on the semi-hexagonal tiles, the lower buttons taking the lugs moulded on the side of the semi-hexagonals to receive them. The semi-cylindrical tiles must fit exactly on the fla tiles, the shoulder of the niche coming in close contact with the lower edge of the flat tile under it, and the battons towards the lower end must lie exactly on the upper edge of the semi-cylindrical tile next beneath it. The three lowest tiles in each layer will be set in lime mortar.

5. Specially made ridge and hip tiles should be used and set in lime mortar. Tiles to be set in lime mortar must be soaked in water for 2 hours before use, and kept well-watered for 7 days after laying.

6. The ends of each row of semi-hexagonal and semi-cylindrical tiles will be filled up with lime mortar, as also the space between the two layers of flat tiles in the double-tiled roof. Special eave-tiles with closed ends may also be specially manufactured.

114. Corrugated Galvanized Iron Roofing

1. The sheets: The C.G.I. sheets will be of 20 to 24 S.W.G 24 guage being the one generally used. The surfa-ce of the sheets must be clean and bright and free from rust; any sheets showing a white powdery deposit should be rejected. The sheets vary in length from 1.8 to 3 m (6 to 10 feet) and in width from 75 to 82 cm (30-33"), the corrugations being about 7.5 cm (3").

2. Laying: The sheets will be laid on horizontal purlins which are fixed at a maximum spacing of 1.3 m (4'-6"). There will usually be one purlin at each end and in the middle of each sheet.-Fig.87.

3. Each sheet should be laid with an end-lap of 15 cm (6 in and a side lap of 2 corrugations, which will be turned away from the rainy quarter.

4. The sheets will be secured to wooden purlins by means of 6 to 8 cm (2½ to 3") galvanized iron screws, or 1 cm (⅜") dia J-bolts, with a screw or bolt at every third corrugation and at all corners and over-laps on each purlin. The holes for these screws or bolts must be punched (or better drilled) from the underside with a sharp tool, and always through a ridge of the corrugation (as laid). A lead or bittumen washer is placed under the head of each screw or bolt and hammered to fit the curve of the corrugation, and the screw or bolt set in white lead paste to avoid leakage.

1. cm. (⅜") dia galvanized iron hooks and J-bolts are available for fixing the sheets to angle-iron and rolled-steel joists.

5. Limpet washers make good and impervious joints, and when screwed down, adapt themselves exactly to the curves of the corrugations and need not be set in white lead.

6. The ridges and hips will be covered with plain galvanized iron sheeting which can be rivetted or fastened with impet washers to the corrugated iron sheets. This sheeting should be laid in lengths with an overlap of at least 20 cm (8") the joints being set in white lead or cement mortar.

7. In windy or exposed places the ends of the sheets at eaves and gables should be fixed by continuous lengths of steel flats 5 x .6 cm (2" x ¼") bolted down to the masonry at about 1.5 m (5') intervals by 12 mm (½") dia bolt 50 cm (18") long, with 15 cm (6") square plate-washers embedded in the masonry.

8. When the sheets are used on deodar wood framing, care should be taken to avoid deodar touching the sheet; otherwise the galvanizing will be destroyed by chemical action.

110. Asbestos Cement Sheet Roofing

1. Asbestos cement sheets are developing rapidly, owing to their cheapness, durability, fire resistence and adaptability. These are mainly 3 types of sheets, generally 1.8 to 3 m (6'-10') in length, as follows:-

Type	Width as laid cm.	ft. in.	Thickness cm.	in.	Side laps cm.	in.	Corrugations No.	Pitch cm.	in.	Depth cm.	in.
Everite Big six	105	3-5½	6	1/4	5	2	7½	14.6	5¾	5	2-1/8
"Standard	76	2-6	6	"	10	4	10	7.3	2-7/8	7	2-⅞
Turnall Trafford	112	2-8	6	"	10	4	4	3.8	13⅞	5	2

2. Laying: The sheets are laid and fixed similar to galvanized iron sheets to wooden purlins by 5 mm (3/16°) dia g.i. driving screws x 10 cm (4") long, or 8 mm (3/16") dia g.i. hooks or bolts to angle iron and joist purlins spaced 1.3 cm (4'-6") apart with an end lap of at least 15 cm (6").

PLATE 15: TO FACE PAGE 61.

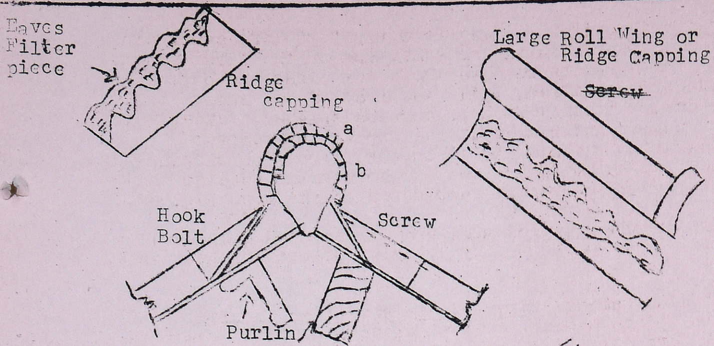

Eaves
Filter
piece
Ridge
capping
a
b
Hook
Bolt
Screw
Purlin
Large Roll Wing or
Ridge Capping
~~Screw~~

Fig:90: A.C. RIDGES & EAVES FILLER PIECES.

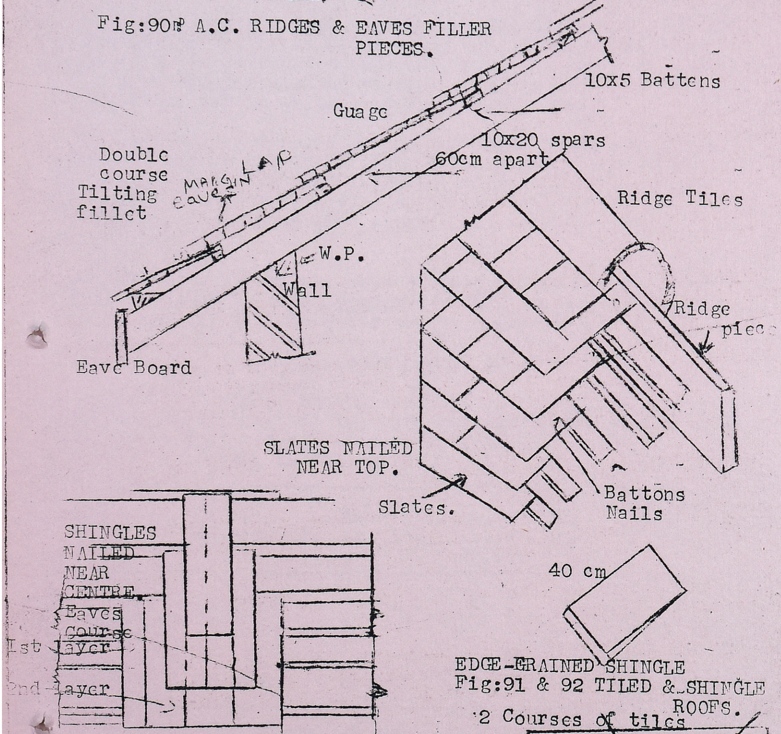

10x5 Battens
Guage
10x20 spars
60cm apart
Double
course
Tilting
fillet
MARGIN
LAP
EAVE
W.P.
Wall
Eave Board
Ridge Tiles
Ridge
piece
SLATES NAILED
NEAR TOP.
Slates.
Battons
Nails
SHINGLES
NAILED
NEAR
CENTRE.
Eaves
Course
1st layer
2nd layer
40 cm
EDGE-GRAINED SHINGLE

Fig:91 & 92 TILED & SHINGLE ROOFS.

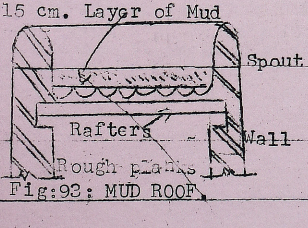

15 cm. Layer of Mud
Spout
Rafters
Wall
Rough planks

Fig:93: MUD ROOF.

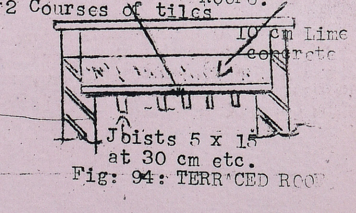

2 Courses of tiles
10 cm Lime
concrete
Joists 5 x 15
at 30 cm etc.

Fig: 94: TERRACED ROOF

3. Trafford Sheets are laid from right to left commencing at the eaves upwards; with the exception of the first sheet, sheets of the eave course have their top right and bottom left hand corners mitred, while the rest of the sheets will all have their bottom left hand corners splayed, (except at verges of gables and ridges). Each splay cut removes a corner measuring the end lap 15 cm (6") along the sloping edge. and a side lap 10 cm (4") along the horizontal edge so that the sheets can be correctly shouldered and mitred, Fig. 88.

4. Big Six and Standard Sheets, are laid exactly similar to the corrugated iron sheets, by splaying the corners suitably. Fig.89.

5. Asbestas Cement ridge and hip sheets are moulded in two pieces, one piece having an external collar fitting over the other and corrugations of the wings fit closely those of the sheets. They are secured to the ridge piece with galvanized iron screws or hook bolts as required, Fig.90.

116. Slate Roofing

1. Natural slate has been used as a roofing material from very early days, particularly in the hills, owing to its durability, toughness and ability to withstand heavy snow free from patches, compact, hard and rough to the touch, and give a clear ringing sound when struck with finger. When soaked in water for 12 hours, it should not absorb water over 1% of its dry weight.

2. Common sizes of slates used varies from 60 x 40 cm (24" x 16") to 25 x 15 cm (10" x 6") the larger sizes being used for flatter slopes.

3. Laying: The ground work for slating consists of wood battens nailed to guage horizontally across common rafters Fig.91. There are two methods of laying slates, the head-nailing and centre-nailing:-

In Head-nailing, nail holes are pierced 3 cm (1") from the head, and guage $\frac{1}{2}$ (length of slate-lap-3 cm).

In Centre-nailing guage = $\frac{1}{2}$ (length of slate-lap). The distance of nail holes from tail end = (guage + lap + a clearance of 1 cm).

In both cases, the holes should be about 3 cm ($1\frac{1}{4}$") from the sides of slates.

4. Centre nailing offers better protection against winds whereas the head nailing gives a better protection to nails. But centre-nailing needs less number of slates and is therefore more commonly used, being less expensive.

5. Slates are laid commencing with a double course at the eaves, the lengths of the first layer slates being equal to guage + lap when centre-nailed, and guage + lap + 3 cm when head nailed. The ridges, hips and valleys will be formed as in the case of Mangalore tiling.

117. Shingles Roofing

1. Shingles:- Wood shingles are thin slabs of hard, straight-grained wood, sawn or preferably split, resembling slates. The most durable shingles in India are those sawn out of teak or deodar woods-Fig.92.

2. The shingles are generally 10 to 15 cm (4 to 6") wide, 30 to 40 cm (12 to 16") long and about 12 mm ($\frac{1}{2}$") thick at the tail or butt end, tapering to about 3 mm ($\frac{1}{8}$") at the head. They are generally cut from quarter logs, and should be rift-sawn, and only the edge-grained shingles should be used for superior work, since they shrink less than the slash grained ones, and have less tendency to warp and split.

3. Shingles are laid over battens 5 x 3 cm (12" x 1") nailed over the common rafters at the required guage, equal to one-nails, passing through the shingles immediately below and just clearing the head of the third; copper or g.i. nails, 3 to 4 cm (1$\frac{1}{4}$" to 1$\frac{1}{2}$") long, are used and are driven in about 3 cm (1") from the edges. A gap of 3 to 5 cm ($\frac{1}{8}$ to $\frac{1}{4}$") should be left between the sides of adjacent shingles, to allow for any swelling in the rains. A minimum lap (distance of the tail end to the nail holes in the shingle below) of 15 cm (6") should be provided.

4. Eaves are closed and have an over-hand of 20 cm (8"). As in slating, a double eaves course is provided, but here they are of full length shingles. The upper eaves courses must break joints with the lower courses, with a minimum side lap of 4 cm (1$\frac{1}{2}$").

5. Hips and Ridges: The usual finish is to nail down narrow strips of 30 cm (12") shingles, each pair being butt joined alternately, or tongued and grooved narrow boarding may be laid with a beading above.

118. Tiling and Shingles over Corrugated Iron

1. Tiling or thatching over corrugated iron sheets reduces the heat, makes the roof neater and move secure, and removes the unbearable noise produced by the rain beating directly on the sheets.

2. Corrugated iron sheets will be laid over purlins as specified in Art.114.

3. Mangalore tiles:- Battens 4 x 2 (1$\frac{1}{2}$"x$\frac{3}{4}$") or 5 x 3 cm (2" x 1") will be secured to the g.i. sheets by means of 6 mm ($\frac{1}{4}$") dia. x 5 cm (2") long galvanized iron bolts at intervals of about 70 cm (28"), the heads being countersunk in the battens, at a guage of 32 or 35 cm (12$\frac{1}{2}$" or 13$\frac{3}{4}$") centres as required. Tiles are then laid on the battens as specified for Mangalore tiling.

4. Country Tiles will be laid directly on the corrugated iron sheets, a batten being fixed at the eaves to prevent the tiles from slipping.

5. Shingles:- Sloping battens 4 cm x 4 cm (1½" x 1½") are laid along ridges of the corrugations at 40 to 50 cm (16" to 20") horizontal distance apart, securely screwed down to the purlins below. Between the purlins, battens will be secured to the sheets by 5 c (2") galvanized iron bolts. Horizontal battens are then nailed to these sloping battens and shingles secured to them in the usual manner.

119. Mud Roofing

1. Mud roofing Consists of rammed clay, usually 15 cm (6") thick over roughly shaped planks of palm, mango, toon, Chir, etc. laid down on wooden rafters across the room-Fig. 93.

2. Laying:- The soil will be stiff clay. After excavation, it will be spread out in the Sun for weathering. It is then powdered and heaped up. Water is added and the clay is well mixed by treading with the feet until it assumes the consistency of stiff mortar. This is then laid on the roof and beaten until quite hard.

In about 3 days the surface begins to crack, which should be immediately filled up with fine dry bearth. The upper surface is then mud plastered and leeped with a mixture of cowdung and sandy clay.

3. The roof must be given a slope of 1 in 20 from the centre towards the edges, and water spouts (round burnt clay pipes) provided under the mud parapet walls, about 30 cm (1') thick and 30 cm (1') high.

120. Terraced Roof.

1. The ordinary terraced roof consists of a layers of lime-concrete over one or two courses of flat tiles or thin stone slabs, laid on timber or rolled steel ~~xx~~ joists as may be specified--Fig. 94.

2. Concrete:- The usual composition of lime concrete used for terracing is 1 mortar 2½" broken brick bats of 2 cm (¾") guage. The thickness of concrete layer will be 10 to 15 cm (4½ to 6") when consolidated, with a top slope of 1 in 20.

3. Laying:- The teak, sal, deodar or kail wood joists are placed from wall to wall at 31 cm 12½" centres, the sizes of scantling used being as follows:-

Span metres	Size cmxcm	Span feet	Size cmxcm	Span metres	Size cmxcm	Span feet.	Size cmxcm
2.0	8x8	6	3x3	3.5	8x15	12	3x6
2.5	8x10	8	3x4	4.05	8x18	14	3x7
3.0	8x12	10	3x5	5.0	8x20	16	3x8

Over the joists, ~~xx~~ a layers of flat tiles 30x30 or 30x15 cm (12"x12"x1" or 12"x6"x1") is laid in two courses, one above the other, breaking joints, with their joints well-rubbed and drawn up with lime [illegible]

Alternatively, a layer of thin stone slabs (lime the Kadapa slabs or Porbunder stones in South India) may be laid over the joists, their spacing being adjusted, 30 to 50 cm (12" to 20"), to suit the lengths of slabs available.

3. Lime concrete is then laid over this course of tiles or stone slabs and beaten down with wooden rammers until the mortar is drawn up to the surafce and the mass is well-set.

During the process, the surface should be sprinkled with a mixture of gur and beal fruit pulp in water.

As soon as ramming is completed clean water should be sprinkled on the surface to soften it, and the mortar should be well-rubbed and rendered smooth with a steel trowel. No plaster should, on any account, be given to the surface, since it will produce a surface-skin which will swell and crack during the rains causing leaks.

4. When finished, on the roof should be laid a layer of grass or old mats, covered with a 3 cm (1") layer of sand, and kept saturated with water for at-least a fourtnight.

5. Portland Cement Rendering:- Whilst rendering the top surface smooth by throwelling, 1 kg. of cement is spread per sq.metre (20 lb per 100 sq.ft) of surface to harden it and fill up the pores.

6. Alternatively, 2 or 3 courses of flat tiles 30 x 30 or 15 x 15 cm (12" x 12") or 6" x 6") may be set in lime or cement mortar over the lime concrete. The tiles should be soaked in water 4 hours before being set and sides well rubbed and drawn up with mortar, wiping out the extra mortar with a piece of cloth.

7. Repairing terraced roofs:- If the cracks are very fine, a coat of hot tar will generally render the roof water-tight.

If a number of hair-cracks extend all over the roof a coat of neat cement cream may be applied.

If the cracks are large they must be raked out so as to cut away the uneven and broken edges, until the crack takes the form of a deep fissure with smooth and even edges, at least 6 mm (¼") wide and as deep as can be made with a trowel. The cracks are then thoroughly flooded with water which must be given time to soak-in. The neat cement paste or 1:1 cement mortar should be forced into the crack and smoothed off taking care that no ridge is formed over the roof surface.

121. Madras Terrace Roof

1. The Madras Terrace roof consists of a layer of lime concrete over a course of bricks on edge laid diagonally across the room over the timber joists. Fig. 95.

2. The concrete and timber joists are similar to those specified for ordinary terraced roof.

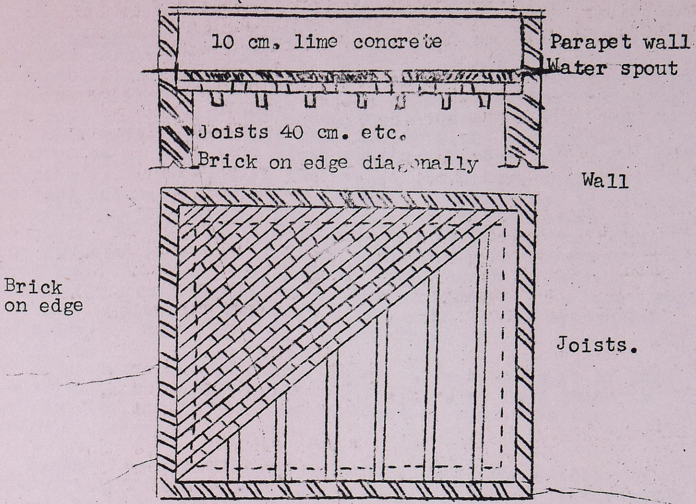

10 cm. lime concrete
Parapet wall
Water spout
Joists 40 cm. etc.
Brick on edge diagonally
Wall
Brick on edge
Joists.

Fig. 95: MADRAS TERRACE ROOF

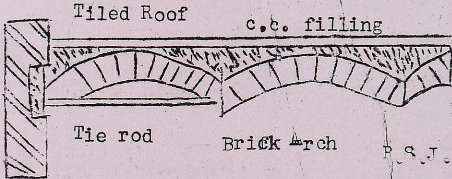

Tiled Roof
c.c. filling
Tie rod
Brick Arch
R.S.J.

Fig. 96: JACK ARCH ROOF

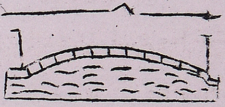


Fig. 97: CONCRETING FOR JACK ARCHES

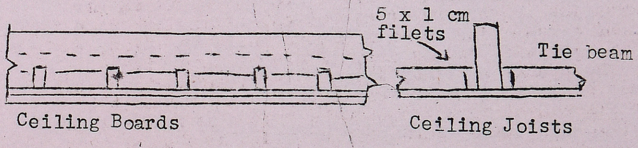

5 x 1 cm filets
Tie beam
Ceiling Boards
Ceiling Joists

Fig. 98: BOARDED CEILINGS.

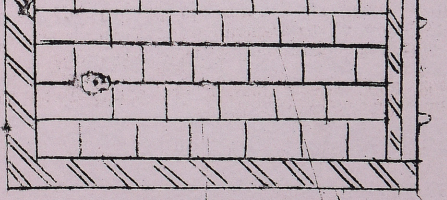


Fig. 99: STONEPAVED EL
STONEPAVED FLOOR - FIRST SORT

3. Laying:- The joints are spaced 25 to 35 cm (10 to 14" centres across the width of the room. A layer of bricks arranged diagonally to the beams is then laid over the joists, commencing from one corner of the room. The first brick or two rest on the wall the mason then covers one side and one end of a brick with stiff lime mortar (1:2) and presses it into place sitting on a joist facing the work; he then presses his foot against the newly laid brick, while he mortars and places the next brick in position and transfers his foot to that brick, and so on until the next wall is reached. He thus works backwards and forwards, completing one row at a time from wall to wall before he commences the next row. The rows should break joint as in an ordinary brick wall, with the bricks soaked in water for 24 hours and the skin allowed to dry before use. The joists are raked next day to give a key for the concrete.

4. When the brick-on-edge course is set, a layer of lime concrete (1 mortar:2½ brick ballast of 2 cm (¾") guage is laid on it, and the surface finished as specified for ordinary terraced roof.

5. The lower surface of the roof, i.e., the ceiling is then neatly finished off with either 3 coats of lime plaster or one coat of 1:3 cement mortar, and white or colour-washed as required.

122. Jack Arch Roofing

1. Jack Arch Roofing consists of a layer of lime concrete over brick-in-mortar or concrete arches carried on rolled steel joists, tie-rods being used to take the thrust in the end arches, Fig.96.

The rise of the arches is generally 8 cm per metre (1" per foot) of span, and the most suitable spacing for joists is 1 to 2 m (4 to 6').

2. R.S.Joists:- The joists should be thoroughly freed from rust by scraping and brushing with steel-wire brushes and kerosene oil, and be given at least 3 coats of paint before being laid in position. R.S.Joists 15 x 7.5 cm @ 5.4 Kg (6" x 3" @ 11 lb) may be used for spans up to 4 metres (12') and with a spacing up to 2 m (6') between joists.

Lime concrete should be as specified for terraced roofings

3. Centering:- The centering may be conveniently supported on the lower flanges of the R.S. Joists, Fig.97. Each wooden center (a 4 cm (1½") plank with its upper surface cut to the shape of the intrados) has fastened to it at each end a bent cleat, by means of which it can be suspended from the lower flanges of the jack arch joists. Either plank or plain galvanized iron sheet lagging may be laid on the centres, on which the arch may be turned.

4. Brick arches:- Generally half-brick rough arches are built up commencing from the upper surface of the bottom flanges of the R.S.Joists.

5. Whie laying concrete arches, the joists are placed on the walls at the required spacing the haunches are filled in first and then the sides and the crown portions filled in up to the specified thickness.

6. ime-rods are placed in the end arches to take in the lateral thrust exerted by the jack arches on the side walls 1.2 to 2 cm ($\frac{1}{2}$ to $\frac{3}{4}$") diameter rods may be placed 8 cm (3") above the bottom of the beam and spaced not further apart than 20 times the width of the beam, i.e. 1.5 m (5').

One end of the rod is fixed in the wall with an anchor plate and the other end bolted to R.S.J.-Fig.96.

7. When the arches are set, the centering is struck, lowered a bit and the arch allowed to settle; it is then left in position until the lime-concrete terracing on top is completed and sets hard.

8. The lime-concrete is laid on top and finished off as specified for ordinary terraced roof.

123. Reinforced Brick-work Roofing

1. These are adopted in the construction of fire-resista floors and roofs, or for large brick canopies over doorways, etc. These are reinforced with rods between the joints of the bricks laid on edge, both transversely and longitudinall, and are supported on R.S. beams or R.C.C. beams spaced not more than 2.5 metres (8') apart.

2. The bricks must be preferably first class, well-burnt and particularly free from lime, set in cement mortar 1:3.

For the top finish, 1:4 cement concrete with 6 to 12 mm ($\frac{1}{4}$ to $\frac{1}{2}$") broken stone ballast will be used.

3. Laying:- The bricks to be used should be soaked in water over night. The reinfordements for the R.C.C. beams, if any are placed in position and concreted.

A brick is placed in edge on either side of the centre of the beam. Then a 12 mm ($\frac{1}{2}$") dia rod, then two more bricks, then the second rod, and so on, or 6 mm ($\frac{1}{4}$") dia rod in every joint, thus ensuring that proper spacing is adhere to. Two masons will start from opposite ends of the room across the short span, and work towards the centre, completi each line of brick already begun. Care should be taken tha each rod is completely surrounded by cement mortar with a cover 2 cm ($\frac{3}{4}$") on the under side of the slab.

Mortar should reach only 2to 2 cm ($\frac{3}{4}$") from top to give a good key to the surface concrete and the brick should be laid so as to break joints. As the work proceeds, every half hour the masons lay the top concrete 3 cm (1") thick on the portion laid before the mortar has had time to set, and proceed laying the bricks again, and so on. In this way the slab is laid continuously and without any portion of the concrete or mortar being allowed to take its initial set before the neighbouring portion is laid.

The concrete should be carefully trowelled smooth with a steel trowel and sprinkled with neat cement paste as required.

4. The concrete should be kept wet for at least 14 days after construction.

5. The slab centering and beam sides may be removed after 7 days and the beam bottom after 10 days. The ceiling underneath is then plastered with cement mortar 1:4, and white or colour washed as desired.

6. A top finish of 3 courses of tiles sett in cement mortar 1:2 or lime concrete as specified for terraced roofing may be provided to make the surface further water-proof where required.

124. Flashing, Gutters and Valleys

1. Gutters flashing will be of milled lead weighing 30 kg. per sq.m. (6 lbper sft) in superior work, or of galvanized iron sheeting 18 S.W.G. They must be arranged so as to give free play for expansion or contraction in any direction.

2. When the edges of sheeting are turned up as in gutters against the side of a chimney stack, Fig.132, or against a wall, the edge is left free and another flashing, secured along the joint of the masonry, is bent down over the upturned edges of the gutter sheeting, which should overlap by about 10 cm (4"). Thus one edge of each piece of sheeting, is left free to expand and contract.

The upper edge of the flashing is stepped and tucked into the joints, which should be raked to a depth to 5 cm (2"). each step being cut to keep out the weather.

3. The gutters should have a fall of at least 1 in 100.

4. Down Pipes:- Rain water down pipes are made of galvanized sheet iron bent on a cylindrical core and rivetted with a lap of 2 cm ($\frac{3}{4}$") beyond the rivet heads; or they may be of light cast iron or asbestos cement pipes.

5. Valleys of lead, zinc or galvanized iron sheeting 18 S.W.G. will be not less than 15 cm (6") wide at the bottom and turned up under the roof covering 50 cm (20") on each side.

SECTION 26. CEILINGS

125. General

1. Timber:- The timber shall be of teak, sal, deodar, kail, terminalia or other sound wood as specified. It must be thoroughly seasoned, free from sapwood, shakes, large or dead knots, or serious defects of any kind.

2. Wood work:- Scantlings must be sawn truely straight and square, and full dimensions shown on drawings. Unseen timbers should not be wrought.

Wood wrought, as in beams for roofs, includes all common, jack, hip and valley rafters, ridge pieces, wooden posts, and railing; wood framed and fixed as in trusses includes door and window frames, gates, purlins and bressumers.

3. All mortice and tenon joints must fit fully and truely, without wedging or filling. Joints should be simple and the bearing surface, exposed to view, if possible, to ensure correct fit and good workmanship.

Framed joints should always be coated with white lead before the members are fitted together. Joints of planks in battened doors should not be allowed to be coated with glue or white lead.

4. Trusses:- A full size drawing of the truss is first made on a level platform, from which templates of all tenons, mortices, and scarfs, etc. should be made to ensure all the trusses being made of the same size.

5. The ends of all beams and trusses etc. which are to be embedded in the walls and the sides of timbers which are to abut against walls, must be treated with solignum or coated with boiling coal-tar.

6. Where the end of a beam or any wood-work is buried in masonry or brickwork an air-space of 5 mm (¼") should be left at the end, sides and top. No woodwork of any kind should be laid within 50 cm (20") of a fire-place or flue.

7. The exposed edges of beams, purlins, rafters, wooden posts, and bressumers, etc. are best finished with a small bead for the sake of appearance.

126. Boarded Ceiling

1. The boards should be of well-seasoned heartwood, sound and free from defects. The board should be not less than 12 mm (½") thick and not more than 15 cm (6") wide.

2. The boards shall be laid truly parallel and fixed to roof purlins or rafters or to ceiling joists 5 x 10 cm (2"x4"), fixed 60 cm (2') apart to the under-sides of the tie beams of trusses, as may be specified. The ends of ceiling joists are slotted or notched over a 3 x 5 cm (1½" x 2") fillet at each side of the tie beam, and the boards nailed or screwed to them--Fig.98.

The joints in boardings are usually tongued and grooved with shot ends, or rebated and filleted and must be neat and close, the planks being forced up against one another with cramps or wedges before being nailed or screwed.

3. The underside will be planed smooth and free from all irregularities, and varnished or painted as required. The upper side should be painted with solignum in localities where white-ants are prevalent.

SECTION 27. FLOORING

127. General

1. Filling in Foundation trenches:- The trenches are refilled with earth to original ground level in 20 cm (8") layers, well

watered and rammed. After completion of the building, the ground should be carefully dressed with a gentle outward slope, so that the rainwater may flow away quickly.

2. Filling in Basement:- The vegetation within the basement should be cleared, the ground well watered and then moorum or good soil filled in, laid in 20 cm (8") layers, watered and rammed until it is thoroughly consolidated. Filling in to plinth level should be done along with plinth masonry, so that it may be further consolidated by workmen walking on it.

Old brick pieces from demolitions form an excellent filling, if properly rammed. Where sand filling is specified to keep out white ants, or in black cotton soil, it should be clean river sand free from mud, grass, etc.

3. Inner floors must be perfectly level, and verandah floors should be given an outward slope of 1 in 40.

4. A sufficient depth of filling is then excavated below the finished floor level, watered and rammed again before laying the flooring.

128. Earth Flooring

1. The soil used must be loam or clay or moorum, sandy soil being unsuitable. If the earth is fresh and damp, no water need be used, otherwise a little water may be sprinkled on it by hand. The less the water used, better the floor will be.

2. Laying:- The earth will be laid in 10 cm (4") layers, and thoroughly consolidated until little mark is made with the heel of a boot. Gravel or moorum is consolidated in the same way, but plenty of water should be used.

3. Renewals:- In the case of renewals whole of the old floor should be dug upto a depth of at least 8 cm (3") and removed, before any new earth is laid.

129. Stone Paving

1. Composition:- Stone paved floor consists of slabs set in lime mortar over a 8 cm (3") bed of lime concrete (1 mortar: 2 broked stone ballast), laid on well rammed plinth-filling. Fig.99.

2. Paving Ist sort: The stones are chisel-dressed and the courses are made of uniform width so that the joints may run true and parallel from side to side,; Joints should not be more than 5 mm (3/16") thick, the stone edges having been dressed in for 4 cm (1½") from the face.

3. Paving 2nd sort is similar to the above but not quite so finely dressed. The joints may be 8 mm (¼") thick, and the edges of the slabs dressed in for 2 cm (¾") only from the surface.

4. Paving 3rd sort: The stone slabs are only rough-point chisel dressed and laid with 1 cm (⅜") joints and dressed in for only 1 cm (½") from the face.

5. Paving 4th sort: consists of setting irregular shaped and varying size stone slabs, hammer-dressed and laid with 1.2 cm (½") joints. No stone should be less than 20 x 20 cm (8" x 5") and all stones in the same floor should be approximately of the same size.

The last two short of paving are suitable only for minor buildings like cook-houses, dharmsalas, etc.

6. In domestic and office buildings, the thickness of lime concrete bed may be 8 cm (3") consolidated, but in machine shops and stores, it should be at least 12 to 15 cm (4 to 6") thick.

7. Laying:- The plinth-filling is levelled and watered, and the lime concrete bed is laid level for inner rooms and at a slope of 1 in 40 for varandahs, and consolidated by ramming.

The concrete bed is watted and lime mortar (1:2) is spread on it, and each stone slab, well soaked in water, is bedded and tapped down with a wooden mallet, so that it cannot be shaken, and such that no hollows are left beneath it. Each stone should be teasted for hollowness underneath after 14 days, and any hollow sounding stone taken up and re-set with fresh mortar.

8. Pointing:- After laying, the joints should be raked out to a depth of 1 cm (⅜") and pointed with cement mortar 1:3, or asphalt as required.

When the stone flags are to be cement-pointed, the stones are laid against 8 mm (¼") thick wood or iron strips, and aft each row has been laid, the strips are taken up and the open joints at once filled with cement mortar (1:3) flush or slightly below the level of the slabs.

9. Cement pointed floors should be kept wet for at least 7 days after pointing.

130. Brick and Tile Flooring

1. This type of floor consist of 1st class bricks or flat tiles, laid on a 8 cm (3") lime concrete base over a well watered and rammed plinth filling.

2. The plinth filling is excavated to the necessary depth below floor level, well watered and rammed down level. The lime concrete (1 lime: 2 broken stone ballast) is then laid and consolidated.

3. Laying Bricks: The bricks to be used should be soaked in water for 4 hours and laid in lime mortar (1:2) true and level, either in parallel rows breaking joints, or in herring-bone pattern. The joints should not excedd 1 cm (⅜") in thickness, and must be finished off flush, no mortar being allowed to spread over the bricks.

In cement pointing is specified, the joint must be at least 1 cm (⅜") thick; these will be raked while the lime mortar is still soft, to a depth of at least 1 cm (⅜") and filled with rich cement mortar 1:3 or asphalt as required.

2. The cement concrete must be laid before the lime concrete base has set. The surface of lime concrete must be thoroughly cleaned and moistened before laying the cement concrete.

Clean river sand and broken stone ballast graded from 3 to 20 mm (⅛" to ¾") guage from the hardest local stone quarry should be used for the cement concrete layers.

3. Laying Cement Concrete:- Large areas of cement concre are liable to crack, due to contraction during setting. So it is advisable to divide the floor into squares or rectangles each side being 1 to 2 metres (3 to 6'). The edge of each section should be defined by flat bars of steel or wood, thei depth being equal to the full thickness of the cement concrete layer; they should be coated with oil or whitewash to preven concrete adhering to them. Adjoining sections of the floor should be laid on different days.- Expansion Joints.

4. The cement concrete should be laid immediately it is mixed, and spread evenly using a straight edge. It is then well-beaten with 2 kg. (5 lb) wooden rammers until the mortar fomes up to the surface which can now be finished off smooth with a steel trowel. The mason engaged on this work sits on small wooden boards, if he cannot reach the work otherwise.

On no account should the surface of the floor be allowed to be plastered.

5. When the cement concrete has set the dividing bars are removed and joints filled with cement mortar (1:2) and finished off in the same way as the rest of the surface.

A better method would be to use 2 mm (1/16") hoop steel linings, when the joints will be so fine as to suffice for them to be filled with fine river sand.

When joints are undesirable, the hoop steel bars are removed before adjoining sections are commenced and strips of oiled paper substituted.

6. If it is desired to have a fine polish, when the concre has set, the surface is rubbed with hard polishing stones. Various patterns may be cut in the surface when it is still soft.

7. Terrazzo finish:- 2 cm (1") thick cement sand plaster (1:2) is laid on the base course; crushed marble of 3 to 6 mm (⅛" to ¼") guage is spread over the surface and rolled into it; when sufficiently hard (8 or 4 days later), it is ground down to a smooth surface by mechanically operated stone discs.

8. Curing:- When laying is completed, the surface is covered with 5 cm (2") layer of grass, sand or saw dust, and kept wet for 7 to 14 days.

9. Colouring:- If it is desired to colour the floor, colouring materials like red oxide of iron, manganese dioxide (black), yellow ocher, etc. (about 10%) may be mixed with the mortar used for the top cement concrete.

PLATE 17: TO FACE PAGE 73.

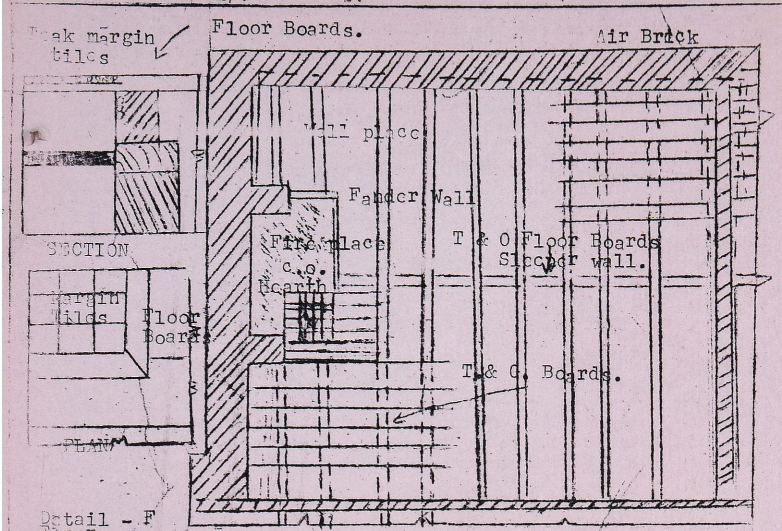
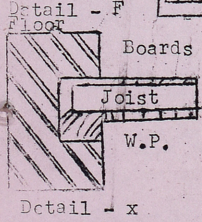

Teak margin tiles
SECTION
Margin Tiles
Floor Boards
PLAN
Floor Boards.
Air Brick
Wall place
Fender Wall
Fire place
c.o.
Hearth
T & O Floor Boards
Sleeper wall.
T & G. Boards.

Fig:100-A: SINGLE (GROUND) FLOOR


Detail - F
Floor
Boards
Joist
W.P.
Detail - x

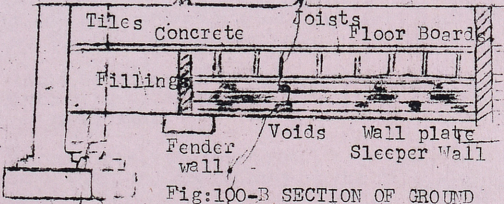

Tiles
Concrete
Joists
Floor Boards
Fillings
Voids
Wall plate
Sleeper Wall
Fender wall.

Fig:100-B SECTION OF GROUND FLOOR.

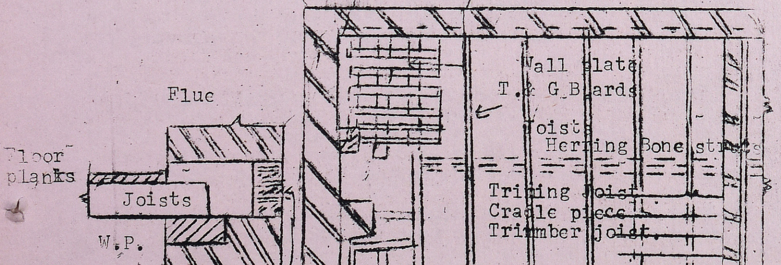

Wall plate
T. & G Boards
Joists
Herring Bone struts
Triming Joist
Cradle piece
Trimmber joist.
Flue
Floor planks
Joists
W.P.
~~Air Bricks.~~
Air Bricks
A - PLAN
Floor Boards
Tiled Hearth
Herring Bone struts
Bridge Joists
B - SECTION

Fig:101: SINGLE(FIRST)FLOOR

133. Wooden Floors

1. Timber:- The floor boards and all joists should be of teak, deadar, kail, terminalia, etc. as specified, but well-seasoned and free from knots or shakes or other defects. The boards are usually 3 to 4 cm (1¼" to 1½") thick, 10 to 15 cm (4" to 6") wide, and 2 to 4 metres (6' to 12') long.

2. Single Floors:- This consists of planking over bridging joists across the width of the room Fig.100. Table below shows suitable sizes of bridging joists:-

Maximum Clear span m	Size of Joist spaced 40 cm. Centres: Live load 250 Kg./m^2 Residences	Size of Joist spaced 40 cm. Centres: Live load 500 Kg./m^2 Offices.	Maximum clear span. ft.	Size of Joist spaced 40 cm. Centre: Live load 50 lb/sft Residence	Size of Joist spaced 40 cm. Centre: Live load 100 ob/sft Offices	Remarks
	cm x cm	cm x cm		in x in	in x in	
2.0	5 x 9	5 x 12	6	2 x 3½	2 x 5	Mean Ex-treme fibre stress 56 kg/cm [illegible] lb/[illegible]
2.5	5 x 11	5 x 15	8	2 x 4½	2 x 6½	
3.0	5 x 14	5 x 2	10	2 x 5½	2 x 8	
3.5	5 x 18	8 x 20	12	2 x 7	3 x 8	
4.0	5 x 20	8 x 22	14	2 x 8	3 x 9	

max.deflectionL/360.

The joists are generally spaced 40 cm (15") centre and their ends rest upon wall plates, generally 10x8 or 8 cm (4"x3" pr.4½" x 3") and are fixed by driving nails through their sides into the wall plates. The upper edge of the joists are levelled by dressing the wall plate slightly as required.

With spans greater than 2.5 m (8') the joists tend to buckle, and hence they should be strutted at not more than 2 m (6') apart.

3. Double Floors. When the width of room exceeds 5 metres (16') the bridging joists are supported on other joists called binders, Fig. 102, placed at right angles to them and spaced at 2 to 3 m (6 to 10') centres. The binders are supported and Bedplates are fixed to them.

4. Triple or framed floors are used in large halls which are both very wide and long. The bridging joists transmit the load to the binders, which in turn are framed into and supported at intervals by larger joists called girders, which span the width of the room, Fig.103.

5. Wgere there are fire-places or hearths in the rooms, no timber joist should be placed in the walls for the full width of the chimney, breasts.

In the case of ground floors, 10 cm (4½") thick dwarf walls, either solid or honey-combed, can be constructed to support the joists, Fig.100B.

In upper floors, Fig.101 D, the ends of the bridging joists are carried by a trimmer joist, placed 60 cm (2') away from the chimney breast and morticed into the two bridging joists on either side of the chimney breasts. These two trimmber joists should be made 3 mm ($\frac{1}{8}$") thicker for each joist supported, which may also be of the same dimensions. The space between the trimmer and the chimney breasts should be covered with a stone or R.C.C. slab.

6. Construction: In masonry walled structures the plinth filling is levelled and a 8 cm (3") layer of lime concrete (1 mortar : 2 broken stone ballast) or cement concrete 1 : 4 : 8 is laid on it.

7. When width of room exceeds 4 metres (12'), intermediate supports for bridging joists may be provided in the form of 9 cm (4½") honey-combed sleeper walls from the concrete surface to underside of wall plate under the bridging joists Fig.100-B. In the case of upper floors, it will be necessary to provide binders and girders, where required-Fig.103.

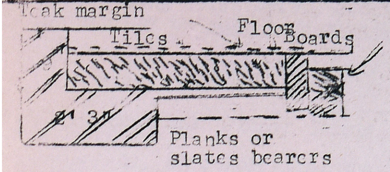
8. To protect timber from dry rot, it is necessary to provi adequate ventilation. The wall plates are, therefore, best supported either (a) by sleeper walls, honey-combed 10 cm (4½") brick walls built parallel to and 5 cm (2") from the main walls or (b) on off-sets in the case of ground floors, or (c) upon corbels in the case of upper floors. If, for economy, the walls plates and ends of the joists are to be built into the wall, it is necessary to form an air space round the ends, sides and tops of the joists, and to apply two coats of creosote or coal-tar, etc. to the wall plates and ends of joists.

A sufficient number of air bricks (perforated bricks) or openings should be left in the external walls below the wooden floor to ensure a free circulation of air. The outer faces of these openings should be covered with expanded metal in preferance to wire netting or perforate zinc plates.

9. The boards will be dressed and planed square and true, with sides and ends parallel. They will be laid perpendicular to the bridging joists and screwed or nailed down over the joists, two at each end and more at every intermediate joist, alternately on opposite sides of the board. The planks should be forced together with carpenter's cramps or wedges; the cramp should not be removed until the screws or nails are fixed.

The nails or floor-brads are driven about 2 cm (1 in) from the ends, and their heads are driven below the surface by using a hammer and punch. The nails or screws generally used are 6 cm (2½ in) oval wire nails.

10. Joints: The edges of the boards will be joined, eithe shot (butt jointed--very poor and should not be used in good work), or rebated (rarely used in edge joints, but can be use in end or heading joints in good work), or tongued and grooved rebated, tongued and grooved (expensive and used in floors where the boards are to be secured by concealed screws or nails), or grooved and filleted (rarely used except where very thick planks are used--Fig.104.


Teak margin
Tiles
Floor Boards
2' 3"
Planks or
slates bearers

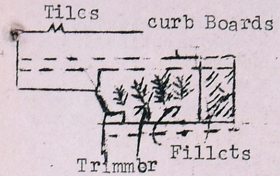

Tiles
curb Boards
Fillets
Trimmer
Arch

Fig:100-B TRIMMING AROUND CHIMNEY BREAST.

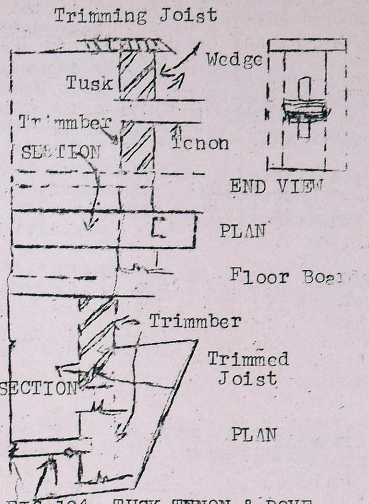

Trimming Joist
Wedge
Tusk
Trimmer
Tenon
SECTION
END VIEW
PLAN
Floor Boa
Trimmer
Trimmed
Joist
SECTION
PLAN

FIG:104: TUSK TENON & DOVE TAILED HOUSED JOINTS.

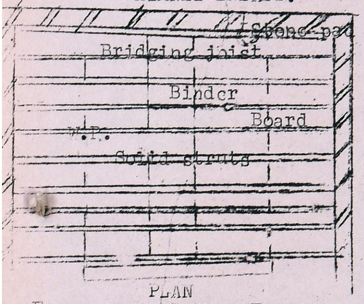

Stone pad
Bridging joist
Binder
Board
W.P.
Solid struts
PLAN

Fig: 101-A: DOUBLE FLOOR

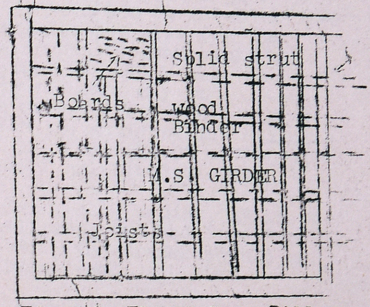
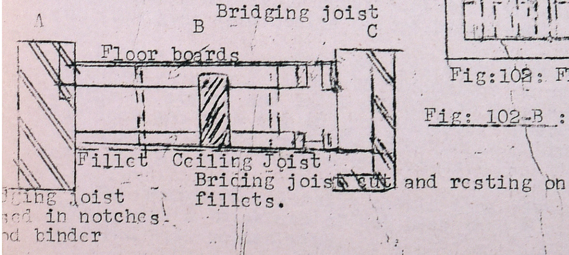
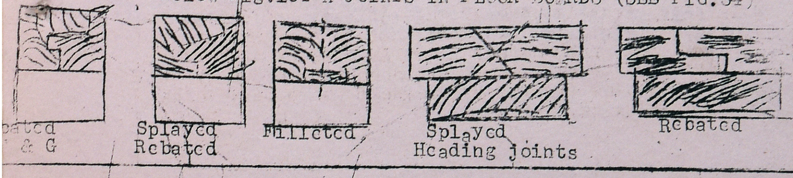

Solid strut
Boards
Wood
Binder
M.S GIRDER
Joists

Fig:102: FRAMED FLOOR Pillar

Fig: 102-B : DETAILED AT A B


A
B
Bridging joist
C
Floor boards
Fillet
Ceiling Joist
Briding joist cut and resting on
fillets.
ging joist
sed in notches
od binder

Below Fig:104-A JOINTS IN FLOOR BOARDS (SEE FIG.64)


bated
& G
Splayed
Rebated
Filleted
Splayed
Heading joints
Rebated

The heading joints in the boards should rest upon a bridging joist below, should break joint with adjacent boards and may be butted or rebated together.

The trimmed joists may be tusk-tennoned, devetailed, housed, bevelled, housed (half depth joint) or square housed into the trimmer joists. Similar joints may be used to connect the trimmer joists to the trimming joists. Fig.101-D.

11. On completion, the boards are planed to a level and smooth surface, either by hand or by machine. Hard-wood floors are afterwards scraped, rubbed smooth with glass-paper and finally oiled or waxed and polished.

12. Floor should be protected against damage during subsequent building operations by liberally covering them with saw dust.

SECTION 28. DOORS AND WINDOWS

134. General

1. The size of doors and windows is the size of the clear opening between the frames or chowkats, no allowance being made for rebating.

The sizes of doors vary considerably, the following standard sizes being generally adopted: 75 x 200 m (2'6" x 6'6"), 80 x 200 cm (2'-9" x 6'-6"), 90 x 200 cm (3'-0" x 7'-0 100 x 220 cm (3'6" x 7'3"). A satisfactory size for the internal door of a modern drawing or dining room would be 105 x 200 cm (3'-6" x 6'-6") and that for bed rooms, store rooms, kitchen, bath rooms, lavatories etc. may be 80 x 200 cm (2'-9" x 6'-6"). The external doors are bigger in order that they may conform with the scale of the building and those of a house are often 90 x 200 cm (3'-0" x 7'-0"), and for an office they may be 100x210 cm (3'-6"x7'-0").

3. The timber used should be teak, sal, deodar, xylia or terminalia or as specified, but well seasoned and free from large knots, shakes or other defects. The planks should be cut from logs some months before being used.

4. The styles, rails, panels, sash bars, etc. should be accurately cut and fitted to dimensions on drawings. The widths of styles and rails should not be less than 8 cm (3 in) for door and 6 cm (2½ in) for windows. Where mortice looks are used, the lock rail should be 20 cm (8 in) wide to allow room for the lock between the tenons.

The tenons of all rails should pass right through the styles with a thickness of not less than ¼ of the style, and fastened with wooden pins.

Sash bars should normally be 2.5 to 3 cm (1" or 1¼") wide with rebates 1 cm (⅜") wide and 2 cm (¾") deep. Sash bars should be properly joined and pinned to the frames, halved into each other, using good quality glue; no nails or screws should be used.

5. All joints should be given a priming coat of paint, before being fastened.

6. Fittings:- The following fittings should normally be provided for door:-

3 pairs of 10 cm (4 in) best iron butt hinges per leaf.
2 best iron tower bolts, 22.5 cm (9 in) and 15 cm (6 in) per leaf.
1 horiz-ontal sliding bolt 30 cm (12 in.) long.
1 handle to match on double leaf door per leaf.
1 Cleat of hard wood with 5 cm (2 in.) iron hinge (or iron hook and eye) per leaf.

7. Locks and other additional fittings must be specially ordered. Brass fittings, parliamentary hinges, mortice locks, etc. are to be specifically provided for in important buildings.

135. Door and Window F

1. Ordinary door frames are made from 8 x 20 cm (3" x 4") scantlings, whereas window frames may be 6 x 10 cm (2½" x 4") - Fig.105.

2. The uprights or posts are haunch-tenoned and fixed into mortices cut in the head and sill (of frames). The head and sill are usually projected (as horns) 15 to 20 cm (6") on either side, which may be buried in the masonry of the wall. Additional horns may be provided to the door-posts for further strength. When the frames are to be fixed later, the horns are omitted, the posts haunch-tenoned into the head and sill, and fastened to the masonry, by iron-hold fasts, made from 5 x 1 cm (2" x 3/8") flats.

Additional rigidity to the frame is provided by inserting 10x2x2cm (3" x 3/4" x 3/4") long wrought iron dowels partly driven into the foot of each door post and partly fixed into the plinth with red lead or cement mortar 1:2.

3. The chowkats are rebated on inside 1 cm (3/8") wide and of the full thickness of the shutter, and has a return head or chamfer on outside, frames carrying shutters on both sides, will be given rebates on both sides, as required.

4. Another rebate 1 x 1 cm (3/8" x 3/8") is cut on both sides of the outer edges of the frame so that the plaster may be carried into it, and prevent appearance of ugly gaps between the frame and the wall jambs - Fig.105.

5. Raised wooden sill in door frames are undesirable, as they obstruct movement and easy clearing and washing of the rooms. Internal doors do not require any raised sill at all, but the sill of the opening may be raised by 1 cm (3/8") (and sloped down to floor level within the reveals), to allow of the door clearing the matting or carpets - Fig.105.

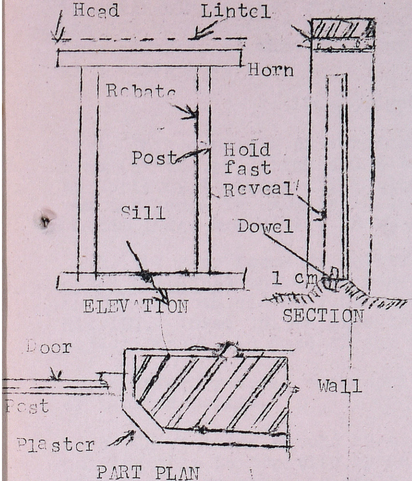

Head
Lintel
Horn
Rebate
Post
Hold fast
Reveal
Sill
Dowel
1 cm
ELEVATION
SECTION
Door
Post
Wall
Plaster
PART PLAN

Fig: 105 THE DOOR FRAME

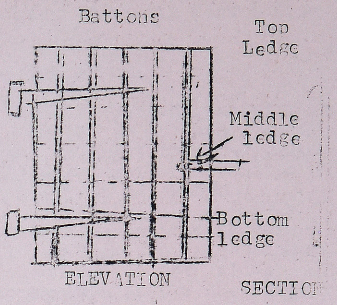

Battens
Top Ledge
Middle ledge
Bottom ledge
ELEVATION
SECTION

Fig: 106: LEDGED BATTEN DOOR.

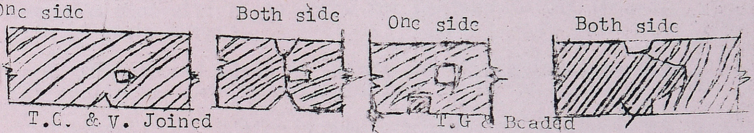
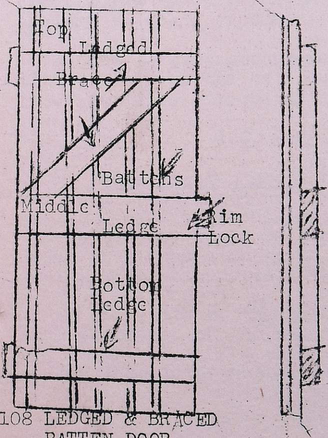
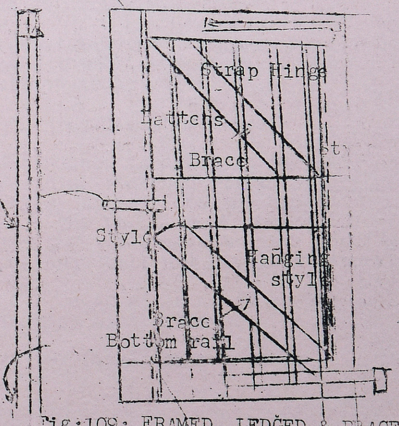

One side
Both side
One side
Both side
T.G. & V. Joined
T.G & Beaded

Fig:107 JOINTS FOR DOOR BATTENS


Top
Ledged
Brace
Battens
Middle
Ledge
Rim Lock
Bottom
Ledge

ig:108 LEDGED & BRACED BATTEN DOOR.


Strap Hinge
Battens
Sty
Brace
Style
Hanging style
Brace
Bottom rail

ig:109: FRAMED, LEDGED & BRACED BATTEN DOOR.

In the case of external doors of forest buildings, it is advisable to have raised wood sills to provide protection against both weather and reptiles etc. and have the doors open inwards, so that they can be secured firmly from inside by a cross-bar.

136. Ledged Batten Doors.

1. This consists of vertical boards or battens, about 2 t 4 cm ($\frac{3}{4}$" to $1\frac{1}{2}$") thick and 8 to 15 cm (3" to 6") wide, secur to horizontal pieces called ledges 3 cm ($1\frac{1}{4}$") thick--Fig.10 The top ledge is usually 10 cm (4") wide, while the middle a bottom ledge are wider, 18 to 22 cm (7" to 9") wide.

2. The four forms of joints between the battens (known as match boarding) which are generally used as T.G. & V-jointed on one or both sides, T.G. & Beaded on one or both sides Fig.107. These joints make the appearance of the door less objectionable, in case of any shrinkage of the battens.

In inferior work, a cheaper door may be made with butt, or rebated joints.

3. The battens should be securely nailed to the ledges, holding them in position by means of cramps. Sufficiently long nails are used, so as to project from the batten side to beyond the ledges, and the ends of the nails are then clinched i.e., bent over and punched into the ledge. A better method will be to screw the battens to the ledges, with 10 guage screws.

4. The exposed edges of ledges may be chamfered or beaded for appearance and prevention/injury by the sharp edge. /of

5. The door is fitted between the rebates of the frame wi a clearance of 2 mm (1/16") being allowed for the thickness of paint and also for expansion. Each leaf will be hung by two wrought iron T-hinges or cross-garnets, or strap hinges 4 cm ($1\frac{1}{2}$") wide, 3 to 6 mm ($\frac{1}{2}$" to $\frac{1}{4}$") thick and 30 to 60 cm (1 to long, which are screwed into the top and bottom ledges, pla against the face of the battens or directly.

6. The locking arrangement generally used is hasp and st with padlock on the outside and a thumb latch on the inside Other fittings will be as specified in Art.134.

137. Ledged and Braced Batten Doors.

1. Ledged Batten Door has a tendency to droop at the fre end, and is strengthened by providing inclined struts or br Fig.108. These braces must incline upward from the hinged edge, otherwise they would be useless. The position of the middle ledge should be such as to allow the two braces to have the same inclination, otherwise the appearance will not be satisfactory.

2. The width of the braces may be 10 to 15 cm (4 to 6") and they should be of the same thickness as the ledges.

3. Other details are same as for Ledged Batten door.

138. Framed, Ledged and Braced Batten Doors

1. This consists of a framing, strengthened by ledges and braces, and the battens. The framework consists of a top rail of thickness equal to that of braces plus battens, tenoned into two vertical members called styles. The middle and bottom ledges are of thickness equal to that of the braces and are tenoned into the styles. The braces are housed into the ledges about 3 cm (1¼") from the styles, or are taken into the corners and tenoned into the styles, the former is a stronger joint, though the latter is commonly used on account of better appearance. These braces must incline upwards from the hanging style--Fig.109.

2. The top rail, generally 10 cm (4") wide x 4 to 5 cm (1½" to 2") thick, has haunched tenon joint with the styles of equal size. The middle ledge 18 to 22 cm (7" to 9") wide and 2 to 3 cm (¾" to 1¼") thick, has a pair of haunched bare-faced tenons (since the ledge is thin) let into the style, and is notched to receive the lower end of the top brace and the top end of the lower brace.

The bottom rail, generally 18 to 22 cm (7 to 9") wide, has also a pair of single barefaced tenons, with the lower one haunched.

The tenons are dowelled or pinned in addition to being wedged, with at least one hardwood dowed or pin through each tenon.

3. The rails are loosely fitted into the styles, the braces a-re placed in position, the battens are accurately fitted and slipped into the grooves of the styles and top rail, and then the tenons are all wedged and pinned, a cramp being used to force the battens together. The battens may be joined with match-boarding joints, their upper ends being let into the top rail, the side battens being tongued into the style, and the lower ends completely covering the bottom rail. (The practice of making the bottom rail to the same thickness as the framing and letting the lower ends of battens into it is unsound, as water will lodge into it and rot both it and the bottom ends of the battens.

4. Hanging:- Heavy wrought iron T-hinges or strap hinges be used to hang this type of door. Two straps are required are secured by 10 to 12 mm (⅜" or ½") dia bolts which are passed through the rail and battens.

But hinges are often used to hang this type of door, in which case three pairs of hinges will be needed.

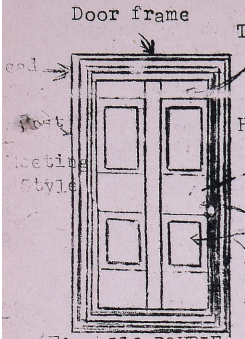
5. Locking and other fittings will be as specified in Art.134.

139. Framed and Ledged Batten doors

1. This is similar to the type described above in Art.138, with the braces omitted. This door tends to become distorted because of the absence of the braces, and hence not generally used these days.

PLATE 20.

TO FACE PAGE 79.


Door frame
ead
Post
Meeting Style

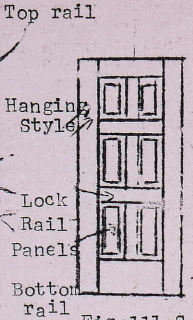

Top rail
Hanging Style
Lock Rail
Panels
Bottom rail

Fig: 110 DOUBLE HUNG PANELLED DOOR

Fig:111:S. SINGLE 6 PANELLED DOOR

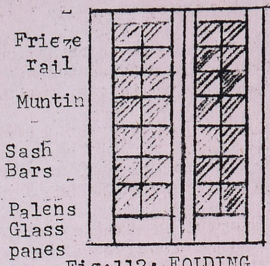

Frieze rail
Muntin
Sash Bars
Palens Glass panes

Fig:112: FOLDING SASH DOOR

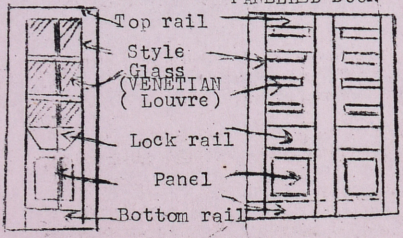

Top rail
Style
Glass
(VENETIAN (Louvre)
Lock rail
Panel
Bottom rail

Fig:113 SASH DOOR.

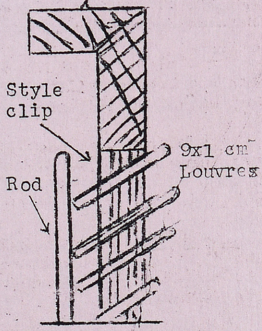
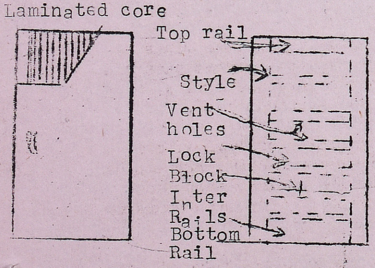
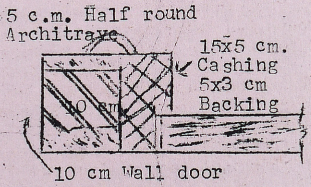

Style clip
9x1 cm Louvres
Rod

Fig:114: VENETIAN DOOR


Laminated core
Top rail
Style
Vent holes
Lock Block
Inter Rails
Bottom Rail


5 c.m. Half round Architrave
15x5 cm. Cashing
5x3 cm Backing
10 cm
10 cm Wall door

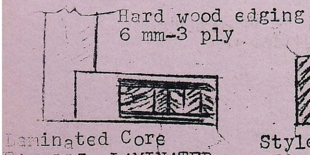

Hard wood edging
6 mm-3 ply
Laminated Core

Fig:115: LAMINATED FLUSH DOOR

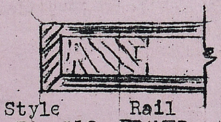
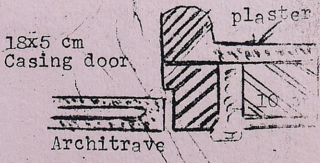


Fig:116 FRAMED FLUSH DOOR.


18x5 cm Casing door
plaster
10
Architrave

117: ~~CASEMENT DOORS~~.

140. Framed and Panelled Doors

1. This consists of a framing or rim which is grooved on the inner edges to receive one or more panels. The framing is similar to that of the frame, and ledged door, except that all rails and styles are of the same thickness, generally 3 to 5 cm (1¼ to 2") - Fig.110.

An additional member which may be necessary in a wide panelled door is a vertical member between the two styles, known as muntin; the muntins are stump-tenoned into the rails. Fig.111.

The middle or lock rail is generally arranged so that its centre is 80 to 90 cm (2'9" to 3'0") above floor level. In tall doors an intermediate rail is provided between the lock rail and the top rail, and is known as Frieze Rail - Fig.111.

2. Thickness of the framing may be 3,4 or 5 cm (1¼", 1 5/8" or 2") depending upon (a) the size of the door, (b) the situation (external doors are generally made thicker than internal doors), (c) the thickness of panels - generally 15, 20 or 25 mm, (½", 3/4" or 1"), and (d) the type of lock to be used, the mortice lock requiring a minimum thickness of 4 cm (1½").

3. The styles, and the top and frieze rails are 10 cm (4") wide, the lock and bottom rails 18 to 22 cm (7" to 9") and the panels out of 12 to 25 mm(½" to 1") thick planking in one piece.

4. Butt hinges are generally used to hang these doors, 3 pairs per leaf being needed. Other fittings will be as specified in Art.134.

141: Glazed Doors

1. Glazed shutters have only 8 cm (3") wide x 3, 4 or 5 cm (1¼, 1 3/8 or 2") thick top rail and styles, while the bottom rail may be 10 or 12 cm (4" or 4½") wide, to improve the appearance and give strength - Fig.112.

The Sash bars or glazing bars are of the same thickness as the framing and 25 to 30 mm (1" or 1¼") wide.

2. The framing is divided into small panels to receive glass panes by horizontal and vertical sash bars. The horizontal bars are continuous with their ends scribed and tenoned into the styles, and are morticed to receive the tenons of the vertical bars.

3. The styles and the top and bottom rails are moulded on one side and rebated 1 cm (3/8") wide on the other to receive glass. The distance between the rebates should be slightly greater than the size of the glass to prevent the glass touching the frame; otherwise even the slightest jeer will crack the glass pane.

The sash bars are similarly moulded on one side and rebated 1 cm (3/8") on the other to receive the glass.

4. The glass is secured to them either by putty or by glazing beads wooden fillets 1 x 1 cm (3/8" x 3/8"), as specified under glazing.

Where putty is used, glass panes are fixed on the outside when door is open; but where glazing beads aare used, the glass panes are fixed on the inside when the door is open.

The glass is usually sheet glass and is specified by its weight per sq.m.(sft) and is 2 to 4 mm (1/16" to 1/6") in thickness.

5. Fittings will be similar to those specified for panelled doors.

142. Framed Doors, half-panelled and half glazed.

1. These are similar to panelled doors, except that the portion above the lock rail is glazed as specified for glazed doors - Fig.115

2. The upper portion of the style of these doors are sometimes made narrower to let in more light and are termed diminished styles.

143. Venetianed Door.

1. A louvre or venetian is an inclined batten set in a containing frame; if used in a series so that the back upper edge of one louvre is above the lower front edge of the next above, the line of vision is obstructed, thus allowing free passage of air but maintaining privacy.

2. The framing will be similar to that of panelled doors, except that the frieze rail is omitted and the panel will be filled in with venetians. Fig.114.

3. The blades should ordinarily be 8 cm (3½") wide and 1 cm (3/8") thick and overlap about half their width. They will be secured to a 2 cm (3/4") moulded stanchion by brass hinges or wire clips, and will have rounded edges.

4. The frame of each shutter is rebated outside all round in the sides and bottom rail, and inside on the top rail. The ends of the blades are rounded off on the centre to 1 cm (3/8") diameter by 2cm (3/4") long, and should fit into holes drilled in the rebated portion of the styles.

5. Locking arrangements and other fittings will be as specified for panelled doors.

144. Wire Guaze Doors.

1. This type of door consists of a framing similar to the glazed door, but with as large panels as practicable (no frieze rail), fitted in with galvanized iron wire guaze, 9 holes to the cm^2 (64 mesh).

2. A 1 cm (3/8 in) rebate is cut on the inside of the frame-work, the wire guaze bent along the rebated surface and secured by 1 x1 cm (3/8" x 3/8") wood fillets or glazing beads, screwed through the bending into the frame-work.

3. The styles and rails may be 3 cm (1¼") thick for a wire gauge door.

4. Wire guage doors should open outwards and be made self-closing by means of spring hinges or weighted cords and pulls or by other contrivance.

5. Fittings will be as for ordinary doors and windows, suitably modified.

145. Flush Doors

1. A recent development is the flush door. The laminated flush door consists of a core of wood strips glued together under pressure and faced on each side by a 6 mm (¼") three-ply-wood, which is also glued under pressure to the core. The core may be of 3 cm (1¼") wide soft wood or 2 cm (¾") wide hardwood strips, placed vertically and glued together, with grains alternating to reduce shrinkage and distoration. A hardwood edging is fixed to cover the core and plywood edges. (Fig.115).

2. The framed flush door consists of two style and the top and bottom rails 8 x 3 cm (3" x 1¼") and thin intermediate rails 3 x 3 cm (1¼" x 1¼") are stub-tenoned into the styles at 20 cm (8") intervals. The joints of the frame are glued and cramped, and the plywood sheets are glued to the framing under pressure. A lock block is also provided for fixing mortice locks--Fig.116.

3. These do not catch dust and are easy to clean, and cou be made decorative by proper veneering for the plywood face. The laminated type is rather heavy and requires much materia and therefore the framed type is more commonly used. The finished thickness of both type of doors is about 4.5 cm (1¾

146. Doors without Hinges

1. Sliding Doors.- These are commonly used for entrances of godowns, shops and garages, and also moved by means of pulleys on horizontal runners at the top. The lower end of the door moves between the guides, which prevent an undue lateral movement.

2. Rolling Steel Shutters:- These can be rolled up and cause no obstruction while opening or closing. They are used for show-room openings, and for entrances to shops, garages, etc.

3. Collapsible Doors:- Flat iron pieces 10 to 15 x 5 mm (⅜" to ⅝" x 3/16") are pinned criss-cross and fixed to vertical flat iron pieces at 10 to 12 cm (4" to 5") centres, supported by rollers on a frame-work. The doors move on these rollers, while being opened or closed.

4. Revolving Doors:- These consist of four shutters arran diagonally on the sides of a central vertical pivot, placed i a circular space of entrance. These may be provided where constant foot traffic of people going in and out of an entran of a public building is to be handled.

147. Casement Doors

1. For thin partition walls, the sides of the openings to take the door shutter may be lined by a single board 15 x 5 c

(6" x 2") over a rough ground of 5 x 3 cm (2" x 1") backing batten, fixed to the jambs of the opening (Fig.117). At the junction of the wall plaster and lining, architrave mouldings are provided to cover the joint and improve the appearance. The head of the frame is provided with horns to be built into the wall.

2. In important public buildings, the internal door openings may be cased in wood frames and stoppers to give improved appearance.

147. Windows General

1. One sq.m. (sft) of window space must be provided every for 25 cu.m. (100 cft) of air in the room in residences and 1 sq.m. for every 12 cu.m (1 sq.ft. for every 50 cft) of air space in hospitals or public buildings or the area of a window opening must be 10 per cent of the floor area of the room. At least half of this window area must be openable.

2. The window should be generally located about 75 cm (2 ft. 6 in.) above the floor level, and all sills in a room must be at the same level. The heights of windows must be adjusted so that all lintels over door and window openings a room are at the same level.

3. When windows are provided for lighting only, they m fixed, in which case sash bars may be fixed to the window frame directly, without any separate sash-frame.

When they are provided for both lighting and ventilatio they may be either (a) hinged vertically on either side, or hinged to top or bottom rail, or (c) hung on pivots near the centres of their sides.

When hinged to top rail, the sash is made to open outward, and when hinged to bottom rail it is made to open inward. When hung on pivots, the upper half is made to swing inwards, (the inside of head and outside of sill being rebated to receive the sash).

4. Another form of window consists of one or more sashes sliding vertically in a cased frame, as in the motor vehicles.

5. The Window Frame: The solid frame is similar to the door frame, with two jambs haunch-tenoned into the head and sill, all 10 cm (4") wide and 6 to 8 cm (2½" to 3") thick.

When the window has two sashes, an additional central member may be provided called a mullion, which is stump-tenoned into the head and sill in a tall window having four shutters, there may be an additional horizontal member in the middle, called the transom, Fig.118.

The frame is rebated 1 to 2 cm (⅜" to ¾") deep to receive the sash. The other edge of the frame may be squa pencil-rounded or chamfered as desired.

The wooden sill is sunk-weathered to cast off rain water. Precautions should be taken to prevent access of r at the bed joint between the wood sill and the brick or st sill, by provision such as (a) a metal water-bar fixed betwe

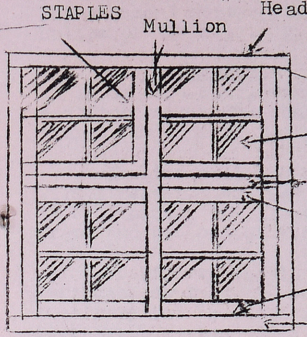
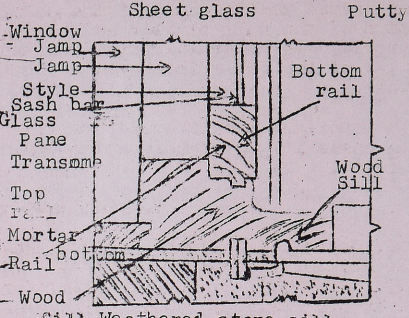

STAPLES
Mullion
Head
Glass
Pane
Transome
Top
rail
Mortar
Rail
bottom

Fig: 118: THE WINDOW FRAME


Sheet glass
Putty
Window
Jamp
Jamp
Style
Sash bar
Bottom
rail
Wood
Sill
Wood
Sill

Weathered stone sill
2x1 cm Galvd. W. Iron
Water bar - bedded in
white lead.
Fig: 119: BEDDING OF
WINDOW SILL

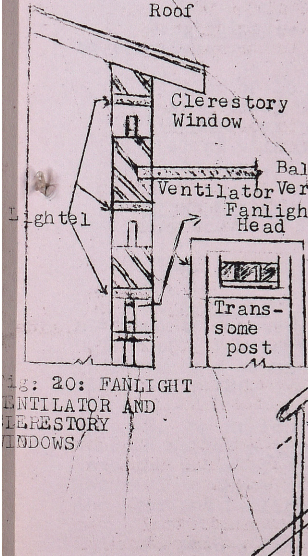
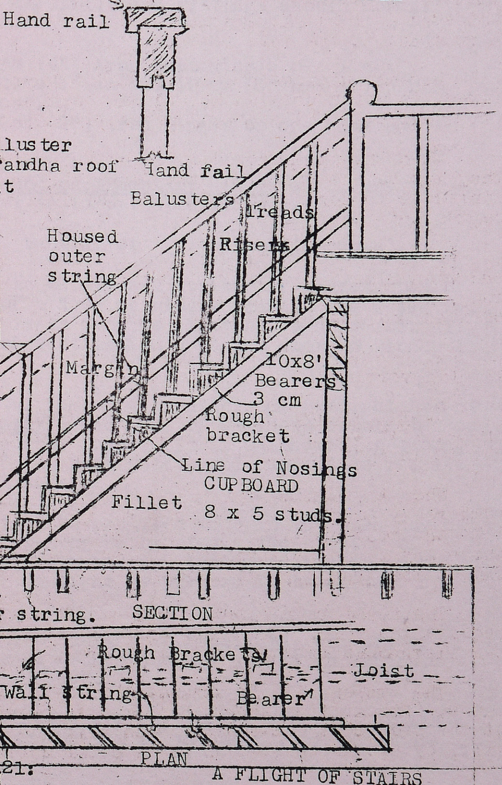

Roof
Clerestory
Window
Balluster
Ventilator
Verandha roof
Fanlight
Head
Lightel
Trans-
some
post

Fig: 20: FANLIGHT
VENTILATOR AND
CLERESTORY
WINDOWS


Hand rail
Hand fail
Balusters
Treads
Risers
Housed
outer
string
Margin
10x8'
Bearers
3 cm
Rough
bracket
Line of Nosings
CUPBOARD
Fillet
8 x 5 studs.
Outer string.
SECTION
Rough Brackets
Joist
Wall string
Bearer
PLAN

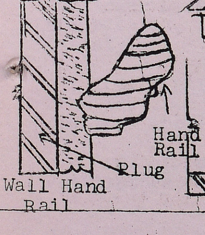

Hand
Rail
Plug
Wall Hand
Rail

Fig.121: A FLIGHT OF STAIRS

the bottom of the wood sill and top of the brick sill; or (b) a cement mortar (1:2) tongue formed in a groove at the bottom of the sill. Fig.119.

6. The Sashes:- The members of a window sash are similar to those of a door, viz. two vertical styles, a top rail and a bottom rail. The construction of the sashes is exactly similar to that of the glazed door.

The top rail and styled are generally 5 cm (2") wide with a deeper 6 cm (2½") bottom rail and all 3 to 5 cm (1½" to 2") thick. The glazing bars are equal in thickness to the frame and are out of 2.5 to 3 cm (1" or 1¼") thick stuff.

7. Windows should open outward unless protected by a verandah, so that the rebate will then be on the outside of the frame and prevents rain water getting into the room. Also there is the added advantage of being able to use the window sill for placing small things and flower vases, etc.

8. Wooden shutters for the windows may be of any of the types described for the doors.

9. Fittings:- The following fittings should normally be provided:-

2 pairs of 10 cm (4") iron butt hinges per leaf.
2 iron tower bolts 15 cm and 10 cm (6" and 4") per leaf
1 handle per leaf.
1 cleat with 5 cm (2") iron hinge, or one hook and eye per leaf.

Brass fittings and parlimentary hinges etc., are to be specially provided for in important buildings.

149. Ranlight, Ventilator Clerestory Windows

1. Fanlight is an additional horizontal glazed opening attached to the top of a door or window frame. The essential object of a fanlight is to provide lighting, and occasionally to serve as a means of ventilation when the door or window is closed--Fig.120.

2. The horizontal member separating the fanlight from the door is called a transom, each end of which is double tenoned into the posts of the door frame. It is weathered, grooved, throated to throw off the rain water, and rebated to receive the door and fanlight sash.

3. When a fanlight is required to open the sash may be either bottom-hung, top-hung or pivoted. The outside of the lower half of the frame and the inside of its upper half are rebated, when the fanlight is pivoted in the middle of the styles.

4. Ventilators are similar to fanlights, but are separated from the door and window frames and are housed in separate openings above them, Fig.120.

5. Clerestory Windows are horizontal windows, similar to ventilators, fixed near the top of the main roof and above the

adjoining lean-to or terraced roof of a verandah or side rooms, mainly to provide ventilation to an innder room or main hall- Fig.120.

6. When the fanlights, ventilators and clearestory windows are out of reach, they may be opened or closed by means of a continuous loop of cord, the ends of which are tied to two hooks fixed to the top and bottom rails of the sash.

SECTION 29. STAIRS.

150 GENERAL.

1. A. Stari is a set of steps leading from one floor to another and the portion of the building in which the stair is located is called the staircase. A continuous series of steps is called a flight of steps and there may be one or more flights in a stair between two floors-Fig.

Each step consists of a horizontal tread and a vertical riser, and these are supported by inclined boards, called stringers.

2. A stair may be stright, turning or geometrical Fig. 122.

A straight stair may consist of one or more flights with landings in between.

A quarter-turn stair is one in which the direction changes by 90°, to the right or left, between two floors.

A half-turn stair has its direction reversed eighter by one half-space landing or by a quarter-space landing and a set of winders or by two quarter space landings with a short flight or steps in between. A half turn stair is called a dog-legged stari, when the width of each flight is equal to half the width of the staircase, so that the outer string of the return flight is vertically over that of the foward flight. If there is an open space between the outer strings of the two flifhts, it is called an open-well stairir.

A three quarter turn stair has its direction changed through three right angles, with its upper flight being perpendicular to the lower one.

A Bifurcated stair is one in which the bottom wide flight is divided at a landing into two narrowed flights branching off to the right and left. This is the type common in public buildings in which it appears as a prominent feature. A newel stair is having one a newel post at the foot and head of each flight of steps. An open-well stair with newel is called an Open Newel Stair.

Geometrical or continuous Stair has both the outer string and hand rail continous from bottom to tope and are set out on geometrical principles. They may be arranged in rectangular, polygonal circular or elliptical spaces in plan, and are named accordingly. A geometricals stair, circular in plain and with steps radiating from a central post, is called circular or spiral or helical stair.

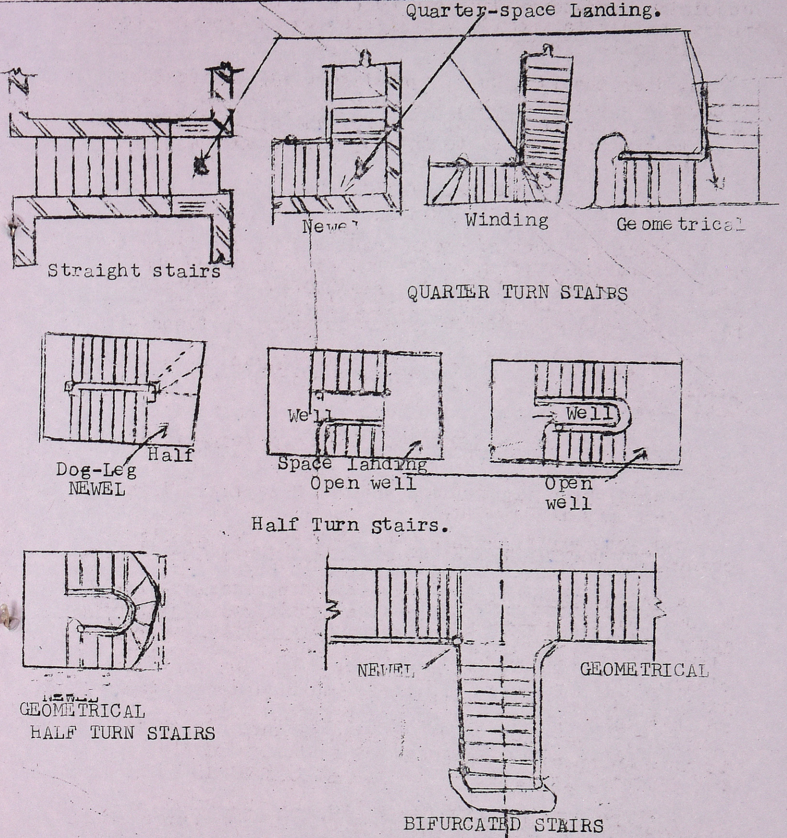

Quarter-space Landing.
Straight stairs
Newel
Winding
Geometrical
QUARTER TURN STAIRS
Well
Well
Half
Dog-Leg
NEWEL
Space landing
Open well
Open
well
Half Turn stairs.
NEWEL
GEOMETRICAL
HALF TURN STAIRS
NEWEL
GEOMETRICAL
BIFURCATED STAIRS

Fig:122: DIFFERENT TYPES OF STAIRS.

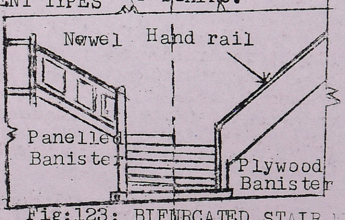
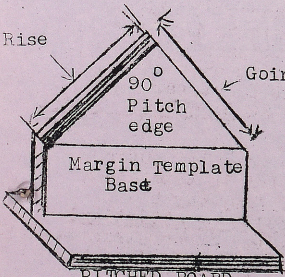

Newel
Hand rail
Panelled
Banister
Plywood
Banister

Fig:123: BIFURCATED STAIR W


Rise
90°
Pitch
edge
Going
Margin Template
Base
PITCHED BOARD

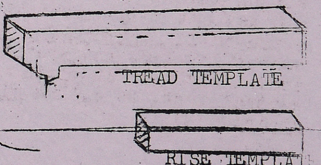

TREAD TEMPLATE
RISE TEMPLATE

Fig:124: THE STRAIR TEMPLATES.

3. Winders are tapering steps, either radiating from a point usually situated in the centre of a newel, or they may form the steps of a geometrical stair.

Walking line is the average line of travel taken by a person in using a stair, and is usually taken to be 45 cm (1 from the centre of the hand-rail or newel.

Head-room is the height measured vertically from the line of nosings to the underside of the trimme joist of the landing or to the soffit of a flight of stair immediately above.

Balusters are short vertical bars fixed to treads of steps, to support a handrail. A banister, on the other hand is a solid penelling support for the handrail--Fig.123.

151. General Principles of Design

1. A well designed stair should be located in such a position that it can be conveniently approached from the lower rooms and afford a ready access to the upper rooms. Doors should be situated at least 30 cm (1") away from the head and foot of a stair, and no door should open on to a landing or head of a stair.

2. It should be well-lighted and ventilated directly from the exterior. A solid banister would require a larger window than an open balustrade. When electricity is available, two-way switches (which enable a light to be controlled by two switches) should be provided at the head and foot of the stair.

3. Its ascent should be relatively easy, and the proportions of treads and risers should confirm to the rules of design. The pitch should not exceed 45° to avoid undue fatigue, and should not be less than 25° to obviate a tedius ascent and undue waste of space.

4. All the risers must be of exactly the same height and all treads of exactly the same width to avoid accidents.

5. The maximum number of steps in any one flight should be limited to twelve, or at the most fifteen. If the height from floor to floor requires more than 15 steps, the stair should be in two or more flights with a landing in between.

6. A single step or two between two adjacent flights is a source of danger. What would otherwise be a half-space landing should never be divided into two quarter space landings by a single riser. If necessary, a short flight of four steps may be provided between two landings.

7. It must be of adequate width. A satisfactory width for an average sized house is 90 cm (3'). A narrower width has a mean look and hinders conveyance of furniture. The clear width of landings must be at least equal to that of a step.

8. A minimum headroom of 2 metres (6' 6") should be provided, 2-05 or 2-10 m (6'-9" or 7'-0") being preferable.

9. Winders must be avoided as far as possible, unless they are arranged as dancing steps. When necessary, they should be so arranged that their width along the walking line is equal to that of a straight step. It is usual to arrange three winders in place of a quarter-space landing.

10. The height of a hand-rail should be 75 to 80 cm (2' to 2' 8") measured vertically above the line of nosings to t top of handrail.

11. Stairs should be constructed of sound materials and workmanship, the treads and risers being properly tongued an grooved together, wedged, glue-blocked and adequately suppo The strings should be well secured to walls, newels, trimme etc. A bearer or rough string should be provided when the stair is more than 1 metre (3 ') wide, with an additional b for every 50 cm (18") of width; otherwise excessive deflec will occur and the stair will creak.

152. Step Proportions

1. The following rules must be adhered to:-

(1) Going + twice rise = 55 to 60 cm (23 to 24 inches)

(2) Going x rise = 400 to 430 cm^2 (66 in^2).

2. The nosing (protection of the tread beyond the face of the riser) is, of course, extra. Going is the horizontal distance from the face of one riser to that of the next, and the rise is the vertical distance from the top of one tread to that of the next.

3. In public buildings, a 30 cm (12") going and 14 to 15 cm (5½ to 6") rise is generally adopted, while in dwelling houses, due to restricted space, a satisfactory proportion would be 25 cm (10") going and 16 or 18 cm (6½" to 7") rise. A minim going of 22 cm (9") should be aimed at, to avoid discomfor while descending a stair, though a 20 cm going can be used at a pinch.

153. Design of a Stair

1. The type of stair depends upon the size and shape of the space available, and the number of steps on the total going available.

2. When the going is unrestricted, the number of risers can be found by dividing the floor height by the proposed rise--between 15 and 18 cm (6" to 7") and the number of treads will be one less than this, since the head of the s will act as tread to the last step. The going is then dec from one of the two rules given above.

3. If the going of the flight is restricted, a minimum going of 22 cm (9") is adopted and the required rise calculated from the rule. The number or risers required to cover the floor to floor height is then determined. Taking the lower round figure as number of steps, re-calculate the exact rise of each step.

4. The treads are generally out of 3 cm (1¼") planks, s that the nosing (i.e., the projection of the tread beyond the face of the riser) should not exceed 3 cm (2¼"). The risers are made from 2.5 cm (1") stuff.

The wall-strings may be 5 x 25 cm (2" x 10") and the outer string (6 x 25 cm) (2½" x 10"), when there are 10 steps of 22 cm (9") going (the maximum number generally used). In a straight stair containing 14 to 16 steps, 5 x 28 cm (2" x 11") wall strings or 6 x 28 cm (2½" x 11") outer housed string may be used. If lath and plaster ceiling is used for the soffit, the depth of the strings should be increased by 8 cm. (3") or the thickness by 3 cm (1"). Thickness is increased by a further 3 cm (1") when an open or cut string is used in place of a housed or closed outer stringer.

The margin generally adopted in a housed stringer is 6 to 8 cm (2½" to 3").

The rough-string or bearer may be 8 x 10 cm (3" x 4") with rough brackets out of 3 x 15 cm (6" x 1") plank pieces. The glue blocks between treads and risers may be out of 5 x 5 x 10 cm (2" x 2" x 4") long pieces spaced about 10 cm(4 apart and one at each tread and stringer joint. The riser and tread wedges taper from 12 mm (½") to 3 mm (⅛") at the tip.

The trimmer joists may be 8 x 20 to 12 x 25 cm (3" x 8" to 5" x 10") for spans 2 to 3 metres (7 to 10') respectivel The landing joists may be 5 x 10 cm (2" x 4") at 30 cm (12" centres for spans upto 1.2 m (4') with trimmers 8 x 10 cm (3" x 4"), when the top newel is carried down to floor leve as support, or with the trimmer tenoned into a newel at one end and supported by wall at the other.

The newels are out of 10 x 10 cm (4" x 4") material.

The hand-rails are shaped out of 8x8 cm (3"x3") timber scantlings over balusters out of 5 x 4 cm (2" x 1½") stuff, spaced 10 cm (4") apart. The balusters are housed or tenoned into the hand-rail at their top and strings or cappings at the bottom.

Appearance of the stair will be greatly enhanced if a capping, of say 6 x 3 cm (2½" x 1¼") is notched on to the upper edge of each string.

5. For design purposes, the live load on stairs is taken as 400 kg./sq.m. (80 lbs/sft) on a domestic stair, and 500 kg sq.m. (100 lbs/sft) in public building stairs. The dead loa may be assumed to be 300 kg/sq.m (60 lbs/sft).

154. Construction of Stairs

1. First a plan of the stair case is prepared, showing, to scale, the position of all the doors and windows, the pl each step and landing being shown on it. Then on a storey 4 x 4 cm (1½" x 1½") and sufficiently long, is taken, and o it is marked the exact floor to floor height. This rod is accurately divided into the requisite number of steps and i then used in their setting out.

2. Then three templates are prepared viz., the pitch boar riser and tread templates, Fig.124. The pitch board is a th wooden set-square, having one side equal to the rise and th other side equal to the going of the steps. This is tongued into a thicker board of width equal to the required margin, and this latter is housed to a wood base at right angles. The riser template and tread template are shaped to the required cross-section of the riser, and the tread includin the nosing, and of a thickness including that of the wedges.

3. Mark the nosing line at required margin, 6 to 8 cm (2½" x 3") generally, from the upper edge of stringer. Set pitch board against the edge of the stringer and mark off the faces of riser and tread on the stringer, Fig.125. Place the riser and tread templates against the pitch board and pencil-mark their outlines for housings. The pitch board is then slid along the stringer and the next step is marked off in a similar manner.

4. Three or four holes are sunk, with a brance and bit, near the nosing of each step and tangential to the outer faces of the stringers, and the wood in between is chiseled out. This permits of the use of the tenon saw for forming cuts along th marked lines, after which the remaining core is removed by a chisel and the bottoms of the trenchings finally levelled wit a router plane to give a 10 to 12 cm (½") sinking. The secon stringer is then set out and the housings formed similarly.

5. The treads and risers are now formed i.e., tongued, grooved, nosed, cut square to corredt length, and dressed. One method of jointing the tread and riser is to tongue both the edges of the riser into the grooved treads on either sid and screw (preferably) or nail them together, Fig.126. A second method is to tongue the treads at their inner edges, into the risers, Fig.127.

6. The first and last treads are housed into the correspon ding trenches of both the stringers, cramped after being tes for squareness, nailed and wedged. The remaining treads are then inserted between the trenches, each being tested, cramp and glue-wedged in turn. After cutting out the outer projec ting edges of the wedges as required, the risers are inserted and glue-wedged. The treads and risers are then screwed together; and glue-blocks fitted to the inner angles. The treads may also be skew screwed or nailed to the stringers to give additional strength.

7. The wall-string is screwed to plugs fixed in the wall at 60 cm (2') intervals.

8. The outer-stringers may be connected to the floor by means of foundation bolts through cleats or they may be carried through the floor and connected to the hinders carrying the floor. Their upper ends may be connected to floor girders or trimming joists by pairs of single tenons. In Newel stairs, the stringers are connected to them by a pair of single tenon and dowelled or pinned, and the newels fixed to the floor by foundation bolts.

9. The rough string or carriage or bearer is birdsmouth-notched and nailed to a short fillet at the foot (or continu

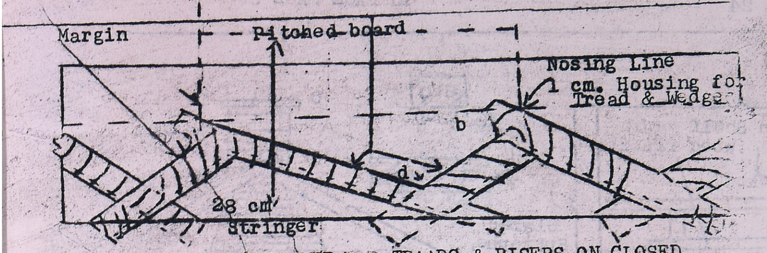

Margin
Pitched board
Nosing Line
1 cm. Housing for Tread & Wedges
b
d
28 cm
Stringer

Fig: 125 : SETTING OUT FOR TRAADS & RISERS ON CLOSED STRINGES.

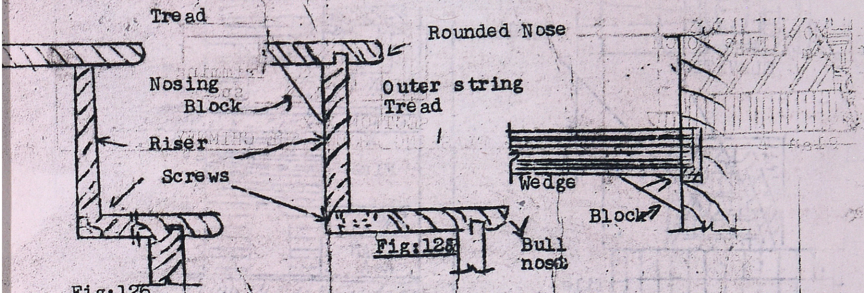
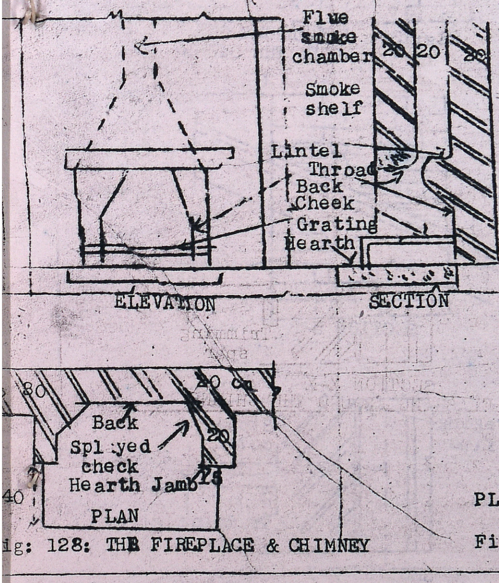

Tread
Rounded Nose
Nosing Block
Outer string Tread
Riser
Screws
Wedge
Block
Fig:125
Bull nose

Fig:126 JOINTS BETWEEN TREADS AND RISERS


Flue smoke chamber
20
20
20
Smoke shelf
Lintel
Throat
Back
Cheek
Grating
Hearth
ELEVATION
SECTION
30
20 cm
Back
Splayed check
20
Hearth Jamb
25
40
PLAN

ig: 128: THE FIREPLACE & CHIMNEY

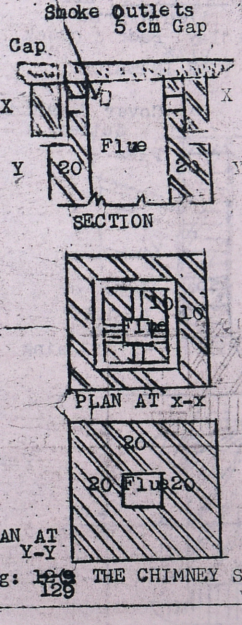
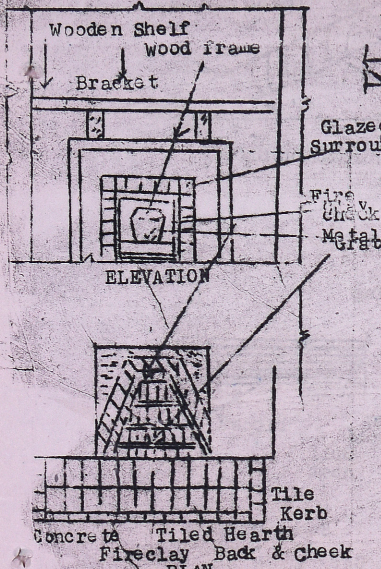

Smoke Outlets 5 cm Gap
Cap
X
X
Flue
Y
20
20
Y
SECTION
10
10
Flue
PLAN AT x-x
20
20
Flue
20
PLAN AT Y-Y

Fig: 129 THE CHIMNEY STACK


Wooden Shelf
Wood frame
Bracket
Glazed Surrouhe
Fire Check
Metal Grate
ELEVATION
Tile Kerb
Concrete
Tiled Hearth
Fireclay Back & Cheek
PLAN

Fi;131: FIRE INTERIOR

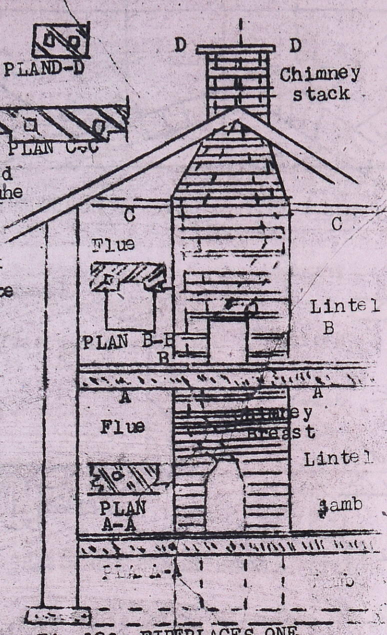
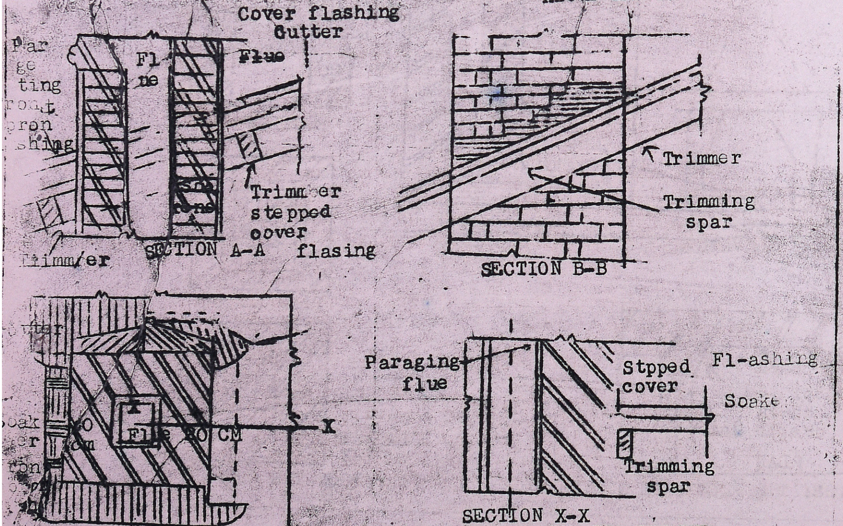

PLAND-D
PLAN C-C
D
D
Chimney stack
C
C
Flue
PLAN B-B
B
Lintel B
A
A
Flue
Chimney Breast
Lintel
PLAN A-A
Jamb

Fig:130: FIREPLACES ONE ABOVE THE OTHER


Cover flashing
Gutter
Flue
Flue
Parge ting
Front
Apron
Flashing
Trimmer stepped cover
flasing
Trimm/er
Trimmer
Trimming spar
Gutter
Soak
X
Flue 20 CM
20 CM
Paraging flue
Stpped cover
Fl-ashing
Soaker
Trimming spar

SECTION A-A

SECTION B-B

Plan A

SECTION X-X

132: FLASHING AROUND THE CHIMNEY

through the floor and connected to floor joist) and similarly secured to a wall plate at the head, 3 cm (1¼") thick short pieces of wood (called rough brackets) are nailed to the sides of the bearer, with their upper edges cut square and brought tightly upto the underside of the treads to which they are nailed skew, these brackets are fixdd alternately to the bearer on opposite sides.

10. Cup-boards and clock rooms may be provided under th stairs to utilize the space.

SECTION 30. FIREPLACES AND CHIMNEYS

155. General

1. In India, a fire-place is generally built mainly for cooking purposes though, in cold hill stations, a fire-place may be provided for living and bed rooms also, to heat the air and make the rooms more comfortable.

2. Location: In living and bed rooms, the fireplace sh be built preferably against an inner wall. Corner hearths not quite satisfactory, as their angle of radiation is limi to 90°. The fire places should always be located away from the door ways, so that people sitting in front of a warm fi place may not be subjected to any outside draught.

156. The Chimney

1. The chimney is a structure which conveys the smoke and other products of combustion from the fire place into the air through a narrow passage called 'flue'--Fig.128. Every fire place must have a separate flue, though two or more such flues may be enclosed in one chimney stack, Fig. 129. The gathering over should be central over the fire-place. A flue must be as straight as possible over most of its length, but there should be at least one bend in a flue to prevent the down-draught and admission of rain water; any bend must be gradual and never at less than 45°. When there are two fire-places, one above the other, the flue from the lower one is taken to one side to clear the upper fireplace, and that fro the upper fire place is taken to the opposite side to avoid smoking chimney, Fig.130. In a single fire place, a smoke shelf (Fig.128) is provided just behind the throat of the chimney to deflect the down-draught of the heavy cold air upwards, so that it might be carried up by the upwa-rd drau of the hot gases from the fire-place.

2. The chimney must be well-bonded with the adjacent and well-bounded.

157. The Fire-Place

1. The jamb projections (Fig.128) of the chimney-bre should not be less than 20 cm (9") thick. The depth of a fireplace should be sufficient to permit the use of 50 cm long sticks where firewood is to be used, but for coke and other fuels, it need be only 50 cm (18") deep.

2. The sizes of fireplaces in living rooms may be of the following dimensions:-

TYPE	WIDTH cm (in)	HEIGHT cm (in)	DEPTH cm (in)	SIZE OF FLUE cm x cm (inx in)
Small	50 to 80 (20 - 30)	60 to 75 (24-30)	40 to 50 (16-18)	20 x 20 (9 x 9)
Medium	80 to 100 (30 - 40)	75 (30)	40 to 50 (16-18)	20 x 20 (9 x 9)
Large	100 to 120 (42 - 48)	75 to 80 (30 - 32)	50 (18-20)	20 x 30 (9 x 13½)
Very large.	120 to 180) (50 - 72)	80 to 100 (34-42)	to to 60 (20-24)	30 x 30 (13½x13½)

3. The head of fire-place is spanned in front with a thi breast wall carried on a flat or segmental arch in two rough half-brick rings or by a stone or R.C.C. Lintel, or on an angle iron frame. For efficient reflection of heat, the upper surface of the back of fireplace should be sloped forward and the jambs splayed inwards towards the back.

4. The back of a fireplace in an internal wall or between two fireplaces built back-to-back in a wall, shall be at lea 10 cm (4½") thick. In a party wall or in an external wall the back shall be at least 20 cm (9") thick to a height of 3 metres (9') above the level of the hearth.

158. The Flue

The flue may be constructed around a wooden frame made to the exact size of the flue to form its shape accurately. The frame is usually 1 to 1.2 metres (3 to 4') long, pulled up as the chimney is raised. The inside of the flue is rendered smooth with 1.2 cm (½") plaster consisting of 1 lime:2sand: 1 cow-dung pargetting. To keep the flue clear of the mortar droppings, pieces of bricks, etc., a core of sack stuffed with wood shavings or loosely filled sand, and tied with a rope, is placed within the flue at its commencement, drawn up as the work proceeds and the droppings removed.

159. The Chimney Stack

1. The Chimney Stack is the portion of the chimney proje above the roof. The width of chimney breast is reduced to width of the stack required from above the ceiling but just below the roof - Fig.130. The minimum height of the stack above the roof must be 1 metre (3') but its maximum height m be limited to 6 times its least width measured from the heig point of intersection.

2. The minimum thickness of the walls of a chimney stack must be 10 cm (4½"), but the appearance will be greatly improved if they are made 20 cm (9") thick in the case of single flues. They should be built in water-proofed cement mortar from 30 cm (12") below the lowest point of intersection with the roof, and the pargetting also must contain cement instead of lime.

3. The top portion of the walls of the chimney stack are built hollow, with two half-brick walls with a gap of 5 to 8 cm (2 to 3") in between, and the smoke out-lets provided in the

inner wall, the total area of the openings being equal to at least 1½ times that of the flue enclosed. The top of the stack is then covered with a 8 cm (3") stone or concrete slab resting on these inner walls, and rain-water out-lets provided through the outer 10 cm (4½") walls at the bottom of the gap.

160. The Hearth

1. The hearth must be of incumbustible material and securely supported. The back hearth (the portion within the fireplace recess) is bedded on the walling of the breast. The front hearth must have a minimum thickness of 18 cm (7"), a minimum extension on beyond the fireplace opening at each end of 15 cm (6") and a minimum projection from the breast of 50 cm (18").

2. No woodwork shall be built in under a fire-place oper within 25 cm (10") of the upper surface of the back hearth. Wood plugs shall not be driven into the wall or chimney brea within 15 cm (6") of a flue or fire-place opening. Woodwor such as joists etc. shall not be built in a wall or chimney breast within 20 cm (9") of a flue or fireplace opening.

3. The external face of a chimney shall be rendered wi cement or lime mortar, not less than 1.2 cm (½") thick, up to the roof.

4. Metal fastenings such as nails, screws and holdfast shall not be placed within 5 cm (2") of a flue or fireplace opening.

5. Fire Interior:- A simple fire-interior consists of a fire-clay block with base concrete, an inclined back and splayed sides or cheeks, a metal (cast-iron) grate, a metal angle or wooden frame, and a surround or 10 cm)4") square glazed tiles, Fig.131. The fireclay block and back should be bedded in mortar or concrete and the tiles bedded on cement rendering.

161. Flashings

1. The materials generally used for flashing is lead and zinc, through plain galvanized iron sheets are used in cheap work.

2. The front Apron Flashing is in one piece, bossed or lead burned to the shape from dimensions taken from the stack. The apron is secured by lead wedges and lead-tacked at the ends to secure the free edges. The lower front end is dressed over the slates, tiles or sheeting, and the up-turn is let in 3 cm (1") into the raked out bed joints in the stack, Fig.1

3. For sides, stepped Cover Flashings are used, made 15 to 20 cm (6" to 8") wide strips, having their upper edg cut into a series of steps, the upper horizontal edge of e step being turned 3 cm (1") into the raked joint. The lo ends of these cover flashings are let into the soakers, th 8 cm (3") up-turns being placed behind the stepped flashin The outer edge of the soakers is nailed to reepers and dre under the tiles, so that any water that may pass through t flashings may be carried down to the top of the apron flas and then on to the roof--Fig.132.

4. For the back of the chimney (on the ridge side) gutter and cover flashing are provided to throw off the rain water to the sides.

5. When the stack passes through the ridge, only the side stepped cover-flashings and two front apron flashings would be needed.

6. The stack masonry may be corbelled out of support the ridge piece, common rafters or prulins, if necessary, and then the flashings provided.

7. For stacks penetrating flat roofs, cement mortar(1:1) benchings may be provided at the junctions

162. Smokeless Chullah or Cooking Range.

1. This is designed to eliminate smoke and soot, and the discomfort due to heat while cooking. It is cheaply built, and there is a lot of saving in firewood. Fig. 133.

2. It consists of an L-shaped duct with two or three circular openings on top of a horizontal leg; the end of the duct is provided with an opening to take in firewood. The hot gases are taken out by means of a flue made of (1) sheet iron, (2) Clay or stone-ware pipes, or (3) a brick chimney; or a flue may be built into the walls of the Kitchen itself. A bigger hole may be had just before the commencement fof flue so that a water pot may be placed on it.

3. The chullah can be lighted and flame maintained by the natural draught ensured by the design, thus eliminating constant blowing in.

4. Only firewood fuel can be used in this, and during cooking all the holes should be used, or an earthen plate cover placed on unused holes; otherwise the chullah will smoke

SECTION 31. LIGHTNING CONDUCTORS

163. General

1. A lightning conductor consists of a continuous strip of conducting material to lead the electrical discharge (lightning) away from the building rapidly to the earth--Fig. 134.

2. A conductor will afford protection over an imaginary cone having the point of the conductor for its apex, and the radius of the base on ground equal to twice the height of the ap above the ground.

164. Materials

1. A copper rod or write rope 12mm (½") diameter, or a copper tape 25 x 3 mm (1" x 1/8") or galvanized iron telegraph wire (No.5 SWG) may be used.

2. The upper terminal or Point :- This should be a solid copper rod 2 cm (¾") in diameter, terminating in a cone the height of which is 1 cm (3/8"). It should project at least 1.5 m (5') into the air above one or more of the highest points of the building -- Fig. 134.

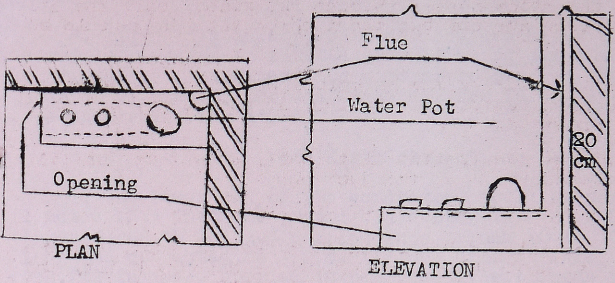

Flue
Water Pot
20 cm
Opening
PLAN
ELEVATION

Fig. 133: THE SMOKELESS CHULLAH OR COOKING RANGE

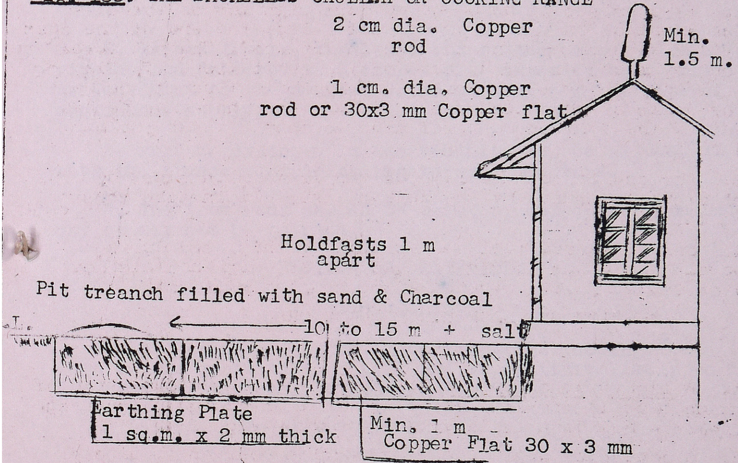

2 cm dia. Copper rod
Min. 1.5 m.
1 cm. dia. Copper rod or 30x3 mm Copper flat
Holdfasts 1 m apart
Pit treanch filled with sand & Charcoal
10 to 15 m + salt
Earthing Plate 1 sq.m. x 2 mm thick
Min. 1 m
Copper Flat 30 x 3 mm

Fig. 134: LIGHTNING CONDUCTOR

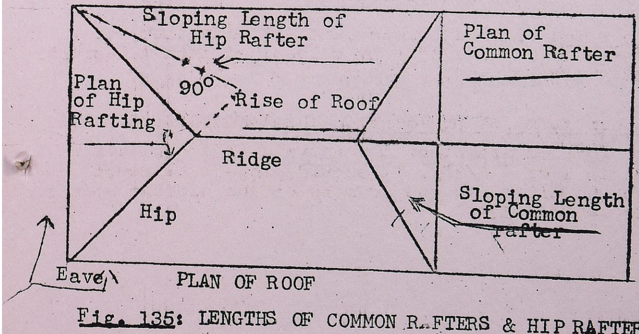

Sloping Length of Hip Rafter
Plan of Common Rafter
Plan of Hip Rafting
90°
Rise of Roof
Ridge
Hip
Sloping Length of Common rafter
Eave
PLAN OF ROOF

Fig. 135: LENGTHS OF COMMON RAFTERS & HIP RAFTERS.

3. The conductor should be attached by proper hold-fasts not farther than 1.2 metres (4') apart. It should preferably be taken down on the most exposed side of the building. It should be encased in a pipe or otherwise protected from injury to a height of 3 metres (10") above ground. All metal surfaces on the roof should be connected to the conductors by copper flats 25 x 3 mm c(1" x $\frac{1}{8}$").

4. All joints in copper tapes besides being well cleaned, scrapped, screwed on rivetted-should be soldered to ensure continuity. Galvanized iron wire or copper rod should be jointed by binding the ends together for 10 cm (4") length and then soldering it.

165. Earth Connection

1. The lower end of the conductor should be carried about 1 metre (3') into the ground; a copper tape 25 x 3 mm (1" x $\frac{1}{8}$") is soldered to it, and carried in a trench 10 to 15 m (30 to 40') long and connected to a 2 mm (1/16") copper plate, over 1 sq.m. (sq.ft) in area, burried in permanently wet earth in a pit. The trench and pit are then filled up with charcoal, salt and sand.

2. Alternatively, the lower end of the copper wire may be riveted and soldered to a copper plug inserted by a coupling or Tee-joint to the nearest water main or service pipe of continuous supply.

3. Surface drainage in the vicinity may be allowed to flow over the trench containing lightning conductors.

4. The iron rods should be painted, but copper conductors may or may not be painted.

SECTION 32. ESTIMATING

166. General

1. An Estimate is a detailed statement showing the calculation of the quantities of work and expenditure likely to be incurred in the construction of a work.

2. It consists of:-

(i) Reference--to correspondence calling for the estimate.
(ii) Report.
(iii) Detailed specifications.
(iv) Design calculations.
(v) Details of measurements.
(vi) Abstract of cost.
(vii) Drawings.

3. The object of preparing an estimate is to know:

(i) the probable cost of the work.
(ii) the quantities of materials required, and
(iii) the time required for completing the work.

167. The Report

1. The report should give the necessity for and object of the proposed work and include a brief general description of the work, mentioning the size and reason for adopting the particular type of design.

2. A note may be added regarding water supply, aspect and access to the work, electrification, roads and drains, the time required for construction, availability of labour and materials approximate cost and how to be financed.

168. Specifications

1. Specification is a detailed description of the nature quality and proportions of the materials to be used, and the method of construction to be followed. It should be carefully and clearly worded so as to allow of only one interpretation leaving nothing to the imagination of the builder

2. The usual headings to be used are Clearing and Levelling of site, Excavations, Foundation, Plinths, Superstructure, Roofs, Ceilings, Floors, Doors and Windows, Joinery, Water Supply, Electrification and Other fittings, Furniture, Roads, Drainage, etc.

3. Design calculations where applicable for roofs, bressummers beams, and reinforced concrete construction, etc., must be attached to the detailed estimate in support of the design.

169. Detailed Measurements.

1. Details of measurements are entered in a tabular statement showing the actual number, length, breadth, height or depth and the quantities of each item of work involved, the dimensions being taken off the working drawings.

2. Quantities need not be taken to more than two decimal places except in the case of woodwork iron and steel work and reinforced cement concrete. The dimensions of wooden scantlings must be given in m and cm. (feet and inches).

170. Abstract of Cost

1. It shows the total quantity of each item of work involved the rate per unit of work and the total cost. The arrangement of the items must follow that adopted in the details of measurements.

2. Contingencies at 5 per cent may be added to the nett total of the abstract of cost. In large works, where a special work-charged establishment is necessary, an allowance not exceeding 2 per cent of the nett cost may be made in the estimate.

171. Drawings

1. A site plan should be prepared showing the location of the work, with respect to the surroundings.

2. A plan (or one plan for each floor in the case of a storeyed building) is drawn which is usually a horizontal

section at the level of the window sills, so that the projections of the plinth, and the positions of all doors and windows may be shown. The directions in which the doors and windows open should be indicated by arrows, and the positions of ventilators and clerestory windows by small cross and the letters V and CSW respectively.

The North point and the direction of the Prevailing Wind must always be indicated on all plans.

3. Front and side Elevations of the structure.

4. One or more vertical Cross-sections of the work to indicate the details of construction.

5. The scales generally adopted for these drawings are as follows:- For plans, elevations and sections, 1 cm = 50 cm (1" = 4'), or 1 cm = 1 m (1" = 8"). For details of parts, 1 cm = 20 cm, (1" = 2'), 1 cm = 10 cm (1" = 1'), 1 cm = 5 cm, (1" = 6") or even 1 cm = 1 cm (1" = 1", i.e., full scale). At least one scale should be drawn on each sheet, to allow of future measurements. The drawings must be fully dimensioned, outside dimensions must be shown conspicuously and not left to be found by adding subsidiary dimensions.

172. Plinth Area and Cube Rate Estimate

1. After taking out the abstract of cost of each building it will be instructive and useful to work out the cost per square metre (square foot) of Plinth Area and also the cost per cubic metre (cft) of the volume of the building. By doing this in several estimates, one soon gets a good idea of what a building of a particular style is likely to cost by merely calculating the plinth area or volume of the proposed building.

2. The cubical contents of a buildings are generally calculated as follows:-

Length x Breadth of the main block (both to outer faces of the walls above the plinth) x height from half way down the bottom of foundation to half-way up the slope of the roof (excluding the projecting eaves), or the top of a flat roof (excluding parapet walls).

Verandahs porches, large chimney stacks, kitchen block, etc. are dealt with similarly but separately.

173. Units of Measurements

The normal units of measurements, on the basis of which rates should be calculated are:-

Description of work	Unit	
1. Earthwork	... 1 cu.m	(1000 cft
2. Rock-blasting, lime, surkhi, mortar, concrete, brickwork, masonry, archwork, rubble, gravel, sand, stone and brick ballast.	... 1 cu.m	(100 cft
3. Cement, iron and steel work	... 1 tonne (50kg.)	(1 dwt 1 ton

Description of work	Unit	
4. Plastering, pointing, painting, white and colour washing, distempering, varnishing, wood oiling, flooring, ceiling, roof-covering.	... 1 sq.m.	(100 sft
5. Wood work, Dressed Ashlar, Reinforced cement concrete.	... 1 cu.m.	(1 cft)
6. Doors and windows	... 1 sq.m.	(1sft)
7. Skirting, beadings, gutters, drains, eave-boards, picture rails, etc.	... 1 m	(1 rft)

174. Taking out Quantities

1. A definite order and system should be followed to avoid omission and also facilitate checking of calculations.

2. Where rates paid are high as in the case of woodwork, custone work, or R.C.C. doors and windows, etc., the dimensions should be taken to the nearest cm ($\frac{1}{2}$") but where rates are rather low as in the case of item 2 above, extreme accuracy is uncalled for, and measurements may be taken to the nearest lm = 10 cm (3"). In the case of a wall, for instance a few cm (inches) here or there in length or height would but little affect the total quantity, but the thickness of a wall, where every cm ($\frac{1}{2}$") affects the volume very appreciably, great care should be exercised in taking out the dimensions.

3. Preparation of site: Depending upon the nature of the work involved, a small lump-sum provision may be made for clearing of site, particularly in forest work, since felling and up-rooting of trees, and also removal of vegetation and weathered soil at the site would be involved.

4. Excavations for foundations: The rate for excavation should include levelling the bottom and dressing the sides of the trenches, refilling of trenches and plinth were required and also removal of excess earth with a lead upto 30 metres (100') and lift upto 1.5 m (5'). It should also cover sloping or shorting up the sides of excavation in ordinary foundations upto 1.5 m (5'). depth.

The rate for rock blasting should include the cost of any blasting materials that may be necessary and of stacking the useful material at one place.

5. Foundations:- The quantities of bed concrete are first taken out and then masonry or brickwork in footing. The simplest way of taking out quantities is to measure the external lengths of walls in one direction (generally the long walls) and the internal lengths of the cross walls. It will be convenient to enter all foundations of the same width and height consecutively as this saves labour of multiplication.

When there are deductions to be made on account of openings or inverted arches, etc. (for which a separate rate is to be paid), these will follow headed "deduction" immediately after the item from which deductions are to be made, and their total substracted from the total obtained in the first instance. The nett total is entered in the last column for transferring to the Abstract of cost.

6. Plinth or Basement: The walls should be considered in the same order as for foundations. The front, rear and other steps may be included under this heading.

7. Superstructure:- Under this head will be entered all walls, piers, pillars, columns, parapet walls, etc. above the plinth. In flat roofed buildings, the height is measured upto the underside of the roof covering and that of parapet walls from above the top of the roof. In pitched roofs the heights of walls are measured upto the top of the common rafters on the centre lines of the walls, the gable portions being taken out separately.

The walls are all first estimated as if solid, neglecting the openings for doors, windows, arch work, lintels, etc., and these taken out separately as "deductionsW.

The Deductions in superstructure should include all door and window openings, arch work, lintels, the different kinds of masonry in jambs and sills, if any, etc. The areas of arched openings may be calculated by multiplying the span x the height (obtained by adding height of springing point + 0.6 times the rise for a segmental arch or 0.75 times the rise for semi-circular or elliptical arch). The length of the arch ring may be assumed to be 1.3 times the span for segmental arches and 1.5 times for semi-circular arches.

In splayed openings, the smallest dimensions should be measured for deductions. No deduction should be made for flues or fireplaces, which are to be calculated as if solid, to allow extra costs involved.

All cornices, corbels, brackets, string courses, etc. must be measured square over the greatest depth and projection for the whole feature, except where a special rate per metre (running foot) is prescribed.

Circular or polygonal columns are calculated as of square cross-section with the diameter as the side of the square and brought under superstructure.

Cut stone work should be measured by the volume of the smallest rectangular block from which it can be cut. The nosing of steps should be covered by the rates of the work.

When deductions from superstructure are completed, the quantities of archwork, brick-in-lime mortar (in case the general work is in mud mortar), stone or R.C.C. lintels may be entered as separate items "as per deductions above", for being carried to the abstract of cost, and it is unnecessary to enter the detailed dimensions of these items again.

8. Roofing:- In Jack arch roofs, the supporting girders archwork, roofing concrete, and ceiling plaster will each be entered under the respective subheads.

In terraced roofs, the terracing may be taken to extend over half the thickness of the walls. The supporting joists and girders etc., are taken out separately and the terracing separately.

In sloping roofs, roof covering includes the battens and the covering materials, but not the supporting rafters or beams and trusses.

In gable roofs, the area of the roof is 2 x (length of eave x sloping length of roof). In hipped roofs, the area is taken out as front and rear trapeziums and the two end triangles.

9. Woodwork:- The dimensions should be measured to the ne cm (half-inch), adding rather than substracting where measurements are doubtful, and making due allowance for over-laps, slanting cuts, etc.

In terraced roofs, the length of bearing on the supporting wall may be taken as half the thickness of wall for joists and two thirds for the beams, if not mentioned definitely.

In pitched roofs the length of common rafter may be measured cut from the cross-section, or calculated as $\sqrt{(\text{half span})\ 2 + (\text{rise})_2}$, . It is unnecessary to find the length of each jack rafter separately for estimating, about half the length of the common rafter being taken as the average length of the jack rafters. Length of hip rafter can be found by drawing an ordinate equal in length to the rise at one end of the hip line in plan and measuring the diagonal--Fig.135.

The number of common rafters in roof of length/metres (ft) when they are spaced s metres (ft) apart is $(\frac{l}{s} + I)$, whereas the number of jack rafters would be $(\frac{l}{s} - I)$.

When dimensions of the woodwork are not shown on the drawing, the following dimensions may be adopted:-

For beams, & purlins, 4 cm (½") wide x 6 cm (¾") deep for each m (ft) on span;

Joists, hip or valley rafters, 2 cm (¼") wide x 4 cm (½") deep for each m (ft) of span;

Common Rafters 1.5 cm (1/8") wide x 3 cm (1/8") deep for each m (ft) of span;
subject to a minimum size of 5 x 8 cm (2" wide x 3" deep).

Woodwork in door and window frames must also be taken out as framed and fixed and included here.

10. Plastering-- Area of plastering is better taken out separately for inside and outside, as the specification often differs in the proportions and also in the ~~a~~ finish, such as white and colourwashing, distempering, etc.

The four sides of each room are measured and multiplied by the height, and then deductions are made for each opening--only half the area of each side of the opening being deducted, the other half being allowed to cover the area of jambs, soffits and sills.

11. White and colour washing and Distempering:-

This item will have the same area as per plasterin and separate detailed measurements are not needed.

12. Flooring:- Measurements are taken up to the wall faces and must include all openings at floor levels. For verandahas, the flooring is generally carried over to th outer edge of the plinth.

The rate will included all subheads of work like the base concrete and the finish, except in the case of wood floors and upper floors, where the supporting members are calculated separately.

13. Doors and windows:- The area is calculated for the opening between rebates in the frame.

The rates for the various classes of doors and windows should include normal fittings as scheduled. Semi-circular doors and windows, and frames should be measured up to the enclosing rectangles.

14. Glazing:- The work should be measured to the nearest centimetre (inch) and curved or irregularly shaped pieces measured as the least containing rectangles. Measurements should be nett from the rebate to rebate.

15. Paintings:- Each kind of painting should be taken out separately, and rates must include cleaning up, etc. at the ed. Mouldings shall be measured by running the tape over and into all the elevations and depressions. Doors and windows will however be measured on the flat, including door and window frames, and paid for as under:-

Type of shutters.	Times one side
Panelled Door or Window ..	2½
pattened and lodged doors and windows	2½
Partly panelled & partly glazed shutters	2
Fully glazed shutters ..	1½
Venetian shutters ..	3½
½ Panelled 2/3 Venetian shutters ..	3

- -

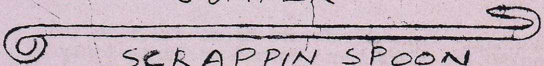
NOTES ON ENGINEERING

Quarrying: blasting with gun powder, dynamite:-

Blasting with explosives:- Blasting consists in boring, deep holes in the rock, loading them with blasting powder, dynamite or other explosive and firing.

The operations which constitute blasting are boring holes, loading and charging. Holes are driven either with a jumper or with a boring bar and a hammer. The jumper is an iron bar 2 to 4 m. long, and 2.5 to 7.5 cm. diameter; having steel chisseledges on either side. Boring bar has one end flat and the other chissel. When large quantities of stone are required, machine drilling is adopted to quarry the stone. Scraping spoon is employed to remove the rock dust from the holes, during drilling.

JUMPER



SCRAPPIN SPOON

Blasting with Blasting powder:- The amount of blasting powder required can be calculated from the value of line of least resistance (L.L.R.) Good results will be obtained by making the depth occupied the tamping material not less than 1½ times L.L.R. Charge (Blasting powder) required per hole in kg.

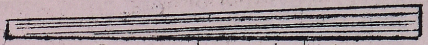
$$= \frac{(\text{L.L.R. in metre})^3}{2}$$

The charge of blasting powder having been poured in, a priming needle of copper or bronze, is inserted in it, the other end of the rod projecting from the bore hole. The needle is greased well. The tamping material consists of ant hill earth or burnt clay powder. This is put little at a time, and rammed down with a brass tamping bar of diameter a little less than that of the hole, and slightly tapering.

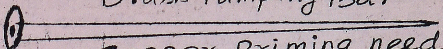
The needle and the tamping bar should never be of iron as this metal strikes sparks which ignite the powder and cause accidents.

When tamping is finished, the needle is withdrawn and the hole left by it is filled with fine grained powder in connection with which is placed piece of fuse. Firing is effected by applying a match to the exposed end of the fuse.

In a good blast the rock loosened is roughly 10,000 times the weight of the powder used.



Brass tamping Bar



Copper Priming needle.

Blasting with dynamite:- Dynamite is nitroglycerine rendered plastic by addition of powdered earth. The earth is called "influsorial earth", which is a deposit of fine, usually white, siliceous material composed mainly of the shells of the microscopic plants (called diatoms). Such materials are inactive and take no part in explosion. In hard rock and submarine blasting, dynamite containing 70% nitrogecering is used, for tunnelling 40 to 50%, for blasting soft rocks, trees, piles, etc. 30%.

Nitrogycerine is made by the careful addition of glycerine to a well stirred and cool mixture of the strongest HNO_3 and H_2SO_4.

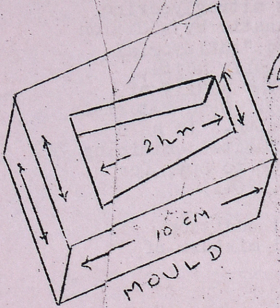
Dynamite is sold in cartridges; $\frac{7}{8}$" and 1" diameter weighing 2 oz. and $2\frac{2}{3}$ oz. respectively. Ignited by ordinary means, dynamite merely flares; to be exploded, it must be fired by a detonating agent such as fulminate of mercury. The detonator is a small copper cylinder about $\frac{1}{4}$" dia. and 1" long with one end closed and containing about 5 to 20 grains of the fulminate. Dynamite will shatter the rock when merely placed on its surface; but for aconomical use bore holes must be employed.

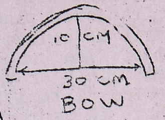
The bore hole having been made, the fuse is pushed into the detonating cap until it touches the white fulminate within the cap. The cap is then compressed with nippers near the open end, to connect it with the fuse. The fuse and the cap being ready, a primer is opened at one end of the cartridge and the cap gently pushed in the dynamite; so that part of it remains visible. The paper of the cap is then closed up and bound securely with wire or twine to prevent displacement of the cap. This is then placed in the bore hole and then fired.

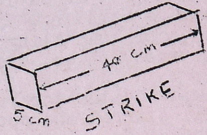
Efflorescence on Brick Work. Efflorescence is the white snow like incrustation that appears on the surfaces of brickwork due to salts which are dissolved by moisture, drawn through the pores to the surface of the wall, and left in thin layers on evoperation of the moisture. It produces ugly damp patches, eats through the surface coatings, and gradually disintegrates the structure. Sulphates of Mg, Ca, and Na, and certain nitrates, carbonates, and chlorides cause efflorescence. $MgSO_4$ is the most dangerous. Bricks if porous, under burnt, or containning pyrites, excess sulphur, or magnesia may cause efflorescence.

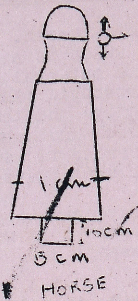
Avoidance of Efflorescence:- Efflorescence can be avoided by the (i) issue of hard-fired bricks (ii) provision of damp proof coubse (iii) use of water free from salts.

Pan tile:- It is similar to the pot tile in shape and differs from it only in being shorter, heavier, and less curved. The implements required are the mould, the bow, the horse and the strike.









First ash is sprinkled over the mould. A lump of clay slightly more than sifficent to fill the mould, is shaped and dashed into the mould and well pressed in all corners. Excess earth is cut away by passing the string of the bow across the surface of the mould. The strike is passed over the clay backwards and forwards, till the surface is tolerably smooth and level with the top of the mould. It is, then taken out of mould and kept aside.

When the tile has dried a little, but still plastic, is horsed. The horse is first aprinkled with ashes. The flat tile is gently bent over it and smoothed into shape with moulders wetted hand. After 5 or 6 hours, when it becomes hard, it is again rehorsed, the ashes cleaned off, and the edges trimmed. It is then, dried and burt.

Burning of tiles: Burning is done with wood. Kiln is circular in shape. Size to hold about 30,000 to 50,000 tiles. Floor of the kiln is made of bricks. The fire must be gentle at first till the disappearance of all white steam, when it may be raised until the interior of the flues has been brought to red heat 1470°F. The fire is again slakened for 6 hours and again raised until the interior of theflues has been brought to white heat 237°F. and kept so for about 3 hours. The fire is then slakened for 6 hours when it is again raised to the same temperature as before which is kept up for about 4 hours. The flues are quite filled with fuel and their mouths closed with brick or mud; and the fire being allowed to burn grzdually out. The burning generally takes 72 hours.

Characteristics of Good tiles:- They should be (a) of shape the regular intended shape and size, free from twists, cracks, flows, and bends and should fit in closely and square when laid in position for work (b) well burnt and of uniform colour (c) possess a clear ringing sound when struck (d) sound and hard.

LIME

Definitions:-

Calcination: is heating to redness in air (1290 to 1470^{0}F).

Quick or caustic lime:- is the result of limestone after burning.

Slaking:- When water to which qudck lime has great affinity, is added it crumbles to powder, evolving much heat and increases in volume by 2½ to 3 times. This powder is slaked lime and process called slaking.

Limestone - calcination - quick lime.

$Ca\ Co_3$ -- $CaO + Co_2$

Quick lime = water

$CaO + H_2O$ =- $Ca(OH)_2$

(Slaking) (Slaked lime)

Hydraulicity:- is the property of the lime or cement has of setting underwater, or in situations free from acess of air when mortar or paste is made from it. It is due to the crystallising energy of the Aluminate and the silicate of lime.

Types of Hydraulic lime:-

(a) Feebly Hydraulic limes: contain 5 to 14% clay or 8 to 12% in all of silica, alumina, magnesia, etc. These slake after a few minutes with crackling, evolve heat and vapour, and reduce to powder. These set 2 to 3 weeks after immersion in water, and become only soap hard after year (b) Moderately hydraulic lime; contains 15 to 20% clay or 12 to 20% in all of silica, alumina, etc. These slake only after an hour or two and that too not violently. Under water these set firm in 7 days and become as hard as soft stone after one year (c) Eminently hydraulic: contains 20 to 30% clay or silica, alumina, etc. These slake with great difficulty after a long period, only slight heat being produced. They set very rapidly attaining the hardness of limestone in 6 months.

Surki:- Fat lime is artificially rendered hydraulic by admixture with puzzolanas "siliceous materials which, though not comentitious in themselves, contain constituents which at ordinary temperature will combine with lime in presence of water to form compounds which have a low solubility and possess cementing properties.

Slaking of Lime:-

Slaking to Paste:- Spread a layer of 6" of fresh quick lime in a wooden or masonry basin and add a sufficient quantity of water so as to submerge it. Quantity of water required is generally 2½ to 3 times the volume of quick lime. Too much of water will check the slaking, too little will result in insufficient slaking, leaving lumps. The surface should be covered by planks to retain the heat of slaking. The lime should not be stirred while slaking.

Slaking to powder:- Quick lime is spread in a layer about 6" to 8" thick and water is sprinkled over it from the rose of the can. The quick lime slakes and is converted into powder.

Burning bricks in Allahabad Flame Kiln:- It is single room without roof, 18' wide, 12' high inside, and of any length varying with the number of bricks to be burned, 44' is the convenient length. Trenches F, 1'3" wide, and 1' deep, are dug across the floor of the room, with intervening spaces of 3'6", Called rouses R. On these rouses sun dried bricks are laid on edges with narrow spaces between for the fire to find its way to and around every every brick. The 8th, 9th and 10th courses of the bricks are corbelled out 2½" to form over the trenches arched passages called flues F. The longitudinal walls have small arched opening corresponding to these flues through which the fuel is supplied and the firing regulated.

Firing:= To commence with there should be slow firing at first to drive out gradually all moisture from the bricks and then the fires are extended into the flues from both sides, and briskly kept up for 3 or 4 days. On ascertaining that all the bricks are burned, all the openings are plastered over with clay, and the kiln allowed to cool gradually for about 8 days.

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RMS